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UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1476

Washington, D. C. ▼ February, 1927

A PROGRESS REPORT ON THE INVESTIGATIONS OF THE EUROPEAN CORN BORER

By

D. J. CAFFREY, Entomologist in Charge, Corn Borer Investigations, and
L. H. WORTHLEY, Administrator in Corn Borer Control, Bureau of Entomology

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INCEPTION AND SCOPE OF THE WORK[1]

The discovery of the European corn borer (*Pyrausta nubilalis* Hübn.) in the vicinity of Boston, Mass., during the summer of 1917, was the first definite intimation that this dangerous foreign pest had gained a foothold on the North American Continent. Stuart C. Vinal,[2] of the Massachusetts Agricultural Experiment Station, who discovered the presence of the insect (*70*),[3] immediately began a preliminary survey and investigation to determine its distribution, biology, economic importance, and methods of possible control or repression under American conditions. This investigation was continued during 1918 in cooperation with the Bureau of Entomology (*71*). In 1919 the project was taken over by the bureau and has since been continued on that basis.

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[1] The investigations reported in this bulletin, covering the period from the spring of 1918 to fall of 1924, have been conducted by D. J. Caffrey and L. H. Worthley, under the direction of W. R. Walton, formerly entomologist in charge, and George A. Dean, senior entomologist in charge, cereal and forage insect investigations, to whom many thanks are expressed for their advice, constructive criticisms, and supervision. The section on distribution and scouting in the United States was prepared by Mr. Worthley, assisted by R. A. Vickery. The sections on seasonal history, seasonal development, and winter mortality of larvae in stored material were conducted and prepared by K. W. Babcock, following the methods suggested by Victor E. Shelford, of the University of Illinois. The descriptions were prepared by W. O. Ellis. The data on seasonal occurrence, and most of the data on life history, habits, predators, and dispersion by water drift, were prepared by G. W. Barber, assisted by W. O. Ellis, K. W. Babcock, L. H. Patch, R. H. Van Zwaluwenburg, D. H. Craig, L. B. Scott, F. L. O'Rourke, J. J. McCarthy, and B. W. Banks. The data pertaining to host plants, infestation and injury to vegetables, flowers, field crops, etc., were prepared by B. E. Hodgson, assisted by F. W. Grigg, L. B. Sanderson, F. S. Vidler, and O. J. Teel. The work on parasites was conducted and reported by D. W. Jones, assisted by H. L. Parker, R. C. Ellis, H. E. Smith, C. W. Smith, and A. N. Vance.

The purpose of this publication is to record the more important results of the investigations upon the bionomics of the insect. The data pertaining to control, as well as to the quarantine and scouting operations, will be issued in a separate publication. Most of the information contained herein has accrued since 1918, through investigations carried on at bureau laboratories located at Arlington, Mass., Silver Creek, Schenectady, and Scotia, N. Y., Sandusky, Ohio, and Hyères, Var, France, together with data obtained during the field control, scouting, and quarantine operations. The information obtained during the cooperative work with the Massachusetts Agricultural Experiment Station (*71*) has also been freely drawn upon, as well as the original report from that station (*70*) announcing the discovery of the insect.

SYSTEMATIC HISTORY AND SYNONYMY

Until the latter part of the nineteenth century not a little confusion existed in foreign literature concerning the systematic history and synonymy of the insect that is now known in America as the European corn borer (*Pyrausta nubilalis* Hübn.).

In 1796 Hübner (*26*, *figs. 94*, *116*) described and figured a male moth from Hungary as *Pyralis nubilalis.* (Hüb., fig. 94.) At the same time he described and figured a female moth from Austria as *P. silacealis.* (Hüb., fig. 116.) The food plant was not mentioned in either instance. It was afterwards shown by Treitschke (*67*, *p. 81*) in 1829 that these supposed "species" merely represented opposite sexes of a single species. According to the law of priority, therefore, the name *nubilalis* is retained for Hübner's species. The error by Hübner, however, led several succeeding workers to adopt the name *silacealis*, which fact contributed to the confusion regarding its synonymy in Europe.

The information pertaining to the eastern New York area was reported by C. F. Turner, J. H. Harman, E. M. Searls, T. R. Richardson, H. D. Smith, J. J. Kelly, and H. P. Wood. In the western New York and Pennsylvania area the information was obtained and reported by H. N. Bartley, L. B. Scott, C. E. Hofer, L. H. Patch, J. J. McCarthy, George Wishart, and H. H. Hodgkiss; and from Ohio and Michigan by F. W. Poos, L. H. Patch, P. A. Howell, H. P. Wood, H. S. Peters, O. L. Cartwright, and E. G. Moore.

Carl Heinrich kindly reviewed the section on systematic history and synonymy. He has also determined larvae, pupae, and adults of *Pyrausta nubilalis*, as well as closely allied species which were reared or collected during the progress of the investigations. J. M. Aldrich, of the United States National Museum; A. B. Gahan and R. A. Cushman, of the taxonomic staff of the bureau in Washington; and C. F. W. Muesebeck, of the gipsy-moth laboratory, have determined the parasitic insects mentioned herein.

Much of the information on the corn borer in Europe has been taken from an unpublished manuscript written (in his capacity as collaborator of the Bureau of Entomology) by J. Jablonowski, director of the Hungarian Agricultural Experiment Station, Budapest, Hungary. (Jablonowski, J., The European Corn Borer and Its Control in Hungary. [Unpublished manuscript. Abstracted by W. R. Walton and J. S. Wade. Mimeographed.]) Professor Jablonowski has studied *P. nubilalis* in Hungary for more than 25 years, and his manuscript includes valuable and complete information relative to the history and distribution of the corn borer in Europe, as well as details concerning its biology in Hungary and the methods of control practiced in that country.

W. R. Thompson, in charge of the European parasite laboratory conducted by the Bureau of Entomology at Hyères, Var, France, has contributed most of the data relative to the parasites of *P. nubilalis* in Europe, as well as a portion of the information pertaining to its habits, seasonal history, economic status, and distribution in France, Belgium, and Italy.

K. W. Babcock, of the Arlington, Mass., laboratory, who began environmental research studies upon *P. nubilalis* in Europe during the spring of 1924, has also contributed information relative to the seasonal history, habits, economic status, and distribution of the borer in Hungary, Italy, Rumania, Yugoslavia, Germany, and France.

[2] Mr. S. C. Vinal, who conducted the initial investigations of this pest with great ability and zeal, died Sept. 27, 1918. It is believed that his untimely death was due largely to his intense devotion to the work. Had he lived to complete his task there is no doubt that he would have contributed largely to the success of the project.

[3] Italic numbers in parentheses refer to "Literature Cited," p. 143.

Haworth (*22*, *p. 380*), 1811, described a species from England as *Pyralis glabralis.* This later was accepted as a doubtful synonym by Hampson (*21*, *p. 435*) and others, although the description is at variance with Hübner's species.

Treitschke (*67*, *p. 81*), 1829, and Duponchel (*15*, *p. 121*, *CCXVII*, *4*), 1831, adopted the name *Pyralis silacealis* Hübn., although recognizing that *nubilalis* of Hübner was the male of *silacealis.* Freyer (*18*, *p. 96*), 1831, Kollar (*34*, *p. 108*), 1840, Herrich-Schaeffer (*25*, *p. 30*), 1849, and Snellen (*59*, *p. 49*) as late as 1882, designated the species as *silacealis* and referred it to the genus Botys erected by Latreille (*38*), 1805.

Guenée (*20*, *p. 331*), 1854, accepted the species as being identical with *Phalaena lupulina* Clerck, illustrated in the Icones Insectorum of Clerck (*11*) in 1759. He therefore designated it as *Botys lupulinalis.* A study of Clerck's figure, however, convinced later workers that Clerck's *lupulina* was not identical with Hübner's species. This interpretation by Guenée, nevertheless, led to the acceptance of the name *lupulina* by several succeeding workers. Heinemann (*23*, *pp. 1*, *2*, *70*), 1865, designated a species from Switzerland as *Botys lupulina.* This is now listed as a synonym of Hübner's species. Butler (*10*, *p. 19*), 1889, referred to the species as *Hapalia lupulina* (non Clerck).

Guenée (*20*, *p. 332*), 1854, described a species from the East Indies as *Botys zealis*, which he regarded as being very close to his *B. lupulinalis*, asserting, "it may be simply a variation of our *lupulinalis.*" This species is now listed as a synonym of Hübner's species, although some authors are not convinced of its validity.

Lederer (*39*, *p. 372*), 1863, retained the species of Botys and accepted the figure of Hübner's *nubilalis* as truly representing the species. This designation was accepted by Staudinger and Wocke (*62*, *p. 209*), 1871, Jourdheuille (*32*, *p. 129*), 1883, Robin and Laboulbène (*52*), 1884, and by Leach (*40*, *p. 32*, *IV*, *4*), 1886.

Moore (*48*, *p. 222*, *pl. VII*, *fig. 28*), 1888, described a species from Kashmir, India, as *Hapalia kasmirica.* This is now listed by Hampson (*21*, *p. 435*) and others as a synonym of Hübner's species. (Specimen in collection of Doctor Staudinger.)

Meyrick (*45*, *p. 416*), 1895, removed the species to the genus Pyrausta, erected by Schrank (*55*) in 1802, and retained *nubilalis* of Hübner, an action which has since been followed by Hampson (*21*, *p. 435*), 1896, and by Staudinger and Rebel (*61*, *p. 65*), 1901.

In 1905 Dyar (*16*, *p. 955*) described a species from Japan as *Pyrausta polygoni* (type a ♀). The specimens were reared from *Polygonum tinctorum.* Dyar differentiated his species from *nubilalis* on several characters, chief among which was the similar coloring of males and females, which character would indeed exclude it as a synonym of *nubilalis.* According to Carl Heinrich, however, the male paratype is badly faded and rubbed, which may account for the lack of characteristic coloring. Its genitalia are identical with *nubilalis* and on that account Mr. Heinrich is of the opinion that *polygoni*, with some reservation, should be considered a synonym of *nubilalis.*

Schultze (*56*, *p. 35*), 1908, described a male and female reared from corn at Manila, Philippine Islands, as *Pyrausta vastatrix* (type a ♀). The very brief description of the male poorly applies to *nubilalis*, but according to Mr. Heinrich, a female in the United States National Museum received from the Philippines as *vastatrix* agrees in oral and genitalic characters with typical *nubilalis*. Mr. Heinrich is of the opinion that *vastatrix*, with some reservation, should be considered a synonym of *nubilalis*.

Reference to the species *Pyrausta nubilalis* Hübner may, therefore, be arranged as follows:

Pyrausta nubilalis Hübner (*26, figs. 94, 116*).
- *Pyralis silacealis* Hübner (*26, figs. 94, 116*).
- *Pyralis glabralis* Haworth (*22, p. 380*).
- *Botys silacealis* Freyer (*18, p. 96*).
- *Botys lupulinalis* Guenée (*20, p. 331*).
- *Botys zealis* Guenée (*20, p. 332*).
- *Botys nubilalis* Lederer (*39, p. 372*).
- *Botys lupulina* Heinemann (*23*).
- *Hapalia kasmirica* Moore (*48, p. 222, pl. VII, fig. 28*).
- *Hapalia lupulina* Butler (*10, p. 19*).
- *Pyrausta nubilalis* Meyrick (*45, p. 416*).
- *Pyrausta polygoni* Dyar (*16, p. 955*).
- *Pyrausta vastatrix* Schultze (*56, p. 35*).

DISTRIBUTION

FOREIGN DISTRIBUTION

Hübner (*26*, *figs. 94*, *116*) in his original record of the species gave its habitat as "Europe, western Asia, the Himalayas, and Assam" (northern India). Foreign literature also refers, in general terms, to the range of *Pyrausta nubilalis* as central and southern Europe (*45*, *p. 416*), Asia Minor (*61*, *p. 65*), west-central and northern (Asia (*45*, *p. 416*), northwestern Himalayas (*21*, *p. 436*), northern India (*61*, *p. 65*), Siberia (*61*, *p. 65*), Japan (*45*, *p. 416*), the East Indies (*20*, *p. 332*), the Philippine Islands (*56*, *p. 35*), and Guam (*8*, *p. 39–40*).

The published records and correspondence of various foreign writers mentioning more in detail the distribution of *P. nubilalis* in the Old World indicate that it is widely distributed in certain districts of the Netherlands, Belgium, France, Italy, Germany (Bavaria), Austria (Vienna district), Hungary, Czechoslovakia (Bohemia), Yugoslavia (Slavonia and Carniola), Rumania (Transylvania and Wallachia), southern and southwestern Russia, including Trans-Caucasia, with apparently isolated areas of infestation in the irrigated regions near the city of Astrakan, and in Livonia (*67*, *p. 81; 20*, *p. 331*).

Meyrick (*45*, *p. 416*) mentioned the occurrence of the species in England (Middlesex, Isle of Wight, Lancashire)—"probably a casual immigrant only."

The species has also been reported from Switzerland (*23*, *p. 1*, *2*, *70*) and Portugal (*44*), and in 1920 the Bureau of Entomology received specimens of *P. nubilalis* larvae from Spain (Madrid). It has also been recorded from the Erivan district of Armenia (*68*); from the Province of Ferghana in Turkestan (*69*); from the Provinces of Kashmir (*48*, *p. 122*, *pl. VII*, *fig. 28*); from Sikkim, Manipur and the Khasi Hills (*21*, *p. 436*) in northern India; from Cairo, Egypt (*19*, *p. 270*); and from the Province of Amur in Siberia (*61*, *p. 65*).

In Japan the occurrence of the species is mentioned by Meyrick (*45, p. 416*) and by Takahashi (*64*). During 1922 adults were submitted to the Bureau of Entomology from Yokohama, Japan. Briggs (*8, p. 39–40*) recorded severe damage by the European corn borer to corn in the island of Guam during the period from 1917 to 1919. Specimens from Guam were submitted to the Bureau of Entomology during 1918 and identified as *P. nubilalis.* A species reared from corn at Manila, P. I., was described as *Pyrausta vastatrix* by Schultze (*56, p. 35*) in 1908. This name is now believed to be a synonym of *P. nubilalis.*

Additional distribution records of the species in Germany and Austria were secured by K. W. Babcock during the summer of 1924. He collected specimens of the eggs, larvae, and pupae in the vicinity of Berlin and examined specimens in the museum at Berlin that were collected near Danzig and at other points throughout northern Germany. Records were also obtained of the presence of the species near Hamburg and in Wurtemburg. In southeastern Austria Mr. Babcock observed *P. nubilalis* in the regions of Gratz, Bruck, Kapfenberg, Boden, and Aflenz, and he received reports showing that the species was present at Klagenfurt, and at Marburg in Yugoslavia. In correspondence W. R. Thompson states that according to a report received by him from Doctor Isaakides, of the Greek phytopathological service, the species frequently causes important damage in the Provinces of Trikkala, Karditza, and Karpenissi in Greece.

By reviewing the foregoing, it will be noted that *P. nubilalis* has a wide geographic range in the Northern Hemisphere extending from approximately latitude 58° north (Livonia) to 13° north (Guam and the Philippines). Its climatic range embraces a very wide contrast of meteorogical conditions varying from the dry steppes of southeastern Russia (Tsaritsyn), where the annual mean temperature averages 44.6° F. and the precipitation 13.11 inches annually, to the warm equable temperatures of Guam, with an average annual mean of 81.7° F. and a mean precipitation of 97.27 inches annually. The species is also present in certain irrigated areas, notably in Egypt, Trans-Caucasia, and southern France, where the temperature is relatively high, but where the rainfall in some cases is not sufficient to mature ordinary crops without irrigation. Riazan in Russia, with an annual mean of 40.3° F., and Guam with an annual mean of 81.7° F., represent approximately the lowest and highest temperature limits within which the insect is known to exist. Judging from this facile adaptability to a wide range of climatic conditions exhibited by the species, it appears reasonable to assume that there would be no climatic barrier to prevent *P. nubilalis* from becoming established over the greater part of the arable regions of the United States wherever its host plants can be grown. In this contingency the economic status of the species undoubtedly would vary in certain areas representing widely different climatic and cultural conditions comparable to the apparent variation in its status within the different areas of its occurrence abroad.

ECONOMIC HISTORY IN THE OLD WORLD

The status of *P. nubilalis* as a serious enemy of corn, hops, millet, and hemp has long been recognized in the Old World, although there are no existing records of it as an important economic pest prior to 1835. At that time it was recorded by Schmidt (*54*) as causing severe injury to millet (*Panicum miliaceum*) in Carniola (Yugoslavia). This author states that, under conditions favorable to the larva, the yields of millet fields attacked by it were reduced by one-twelfth or perhaps even one-eighth. Subsequent foreign literature contains a large number of references to the occurrence of and serious injury by *P. nubilalis* in fields of corn, hops, millet, and hemp; especially in Hungary, Rumania, Yugoslavia, Russia, and France. Some of these reports give definite estimates concerning the degree of actual economic loss sustained, but in many instances the details regarding percentage of infestation and injury are lacking. Mention is frequently made in some of the foreign references, dealing particularly with certain areas where hops, millet, hemp, and broomcorn are attacked by *P. nubilalis*, that the insect is widely distributed in these areas, but that it is normally not abundant enough to be of practical importance.

Judging from all available information it is apparent that in certain areas of the Old World, particularly where corn is grown, *P. nubilalis* becomes periodically abundant and causes severe losses, whereas in other areas it is a widely distributed pest which normally does not cause severe economic losses and seldom becomes destructively abundant.

Most of the foreign authors agree that corn is injured by *P. nubilalis* to a greater extent than any of its other cultivated hosts, although some instances are cited of serious injury to hops, millet, and hemp.

One of the first records pertaining to the European corn borer as a pest in Hungary was by Linderman, early in the nineteenth century, who mentioned it as a pest of Indian corn. Emich (*17*) recorded damage in Hungary to corn, millet, and hemp during the period from 1871 to 1884. Szaniszlo (*63*) reported slight injury to corn and millet at Kolozsvar during 1884. In 1886 Jablonowski (*27*) asserted that some damage was wrought to corn in the Banhegyes district of Hungary. During the period from 1891 to 1893 the same author recorded severe damage to corn from several localities in Hungary, where, in badly infested fields the loss amounted to one-third of the yield, and in at least one field under observation, consisting of about 70 acres, a total loss of the grain was sustained. According to Jablonowski (*28*) the insect was again very injurious to corn in Hungary during 1897. He observed severe injury to corn in at least 11 localities and estimated that the average damage throughout the country was at least one-fourth of the grain. At this time complaints were received from 1.600 to 1,800 official agricultural corresopndents concerning the damage caused by this pest. The same author (*30*) recorded another severe outbreak in Hungary during 1915 and 1916. The damage during that period was reported as being particularly severe in the Bacska, one of the principal corn-growing regions of Hungary. Jablonowski asserts that in 1916 the large landowners of this region estimated their total losses due to corn-borer damage as equivalent to from $8,000,000 to $10,000,000, estimating the value of the corn at war prices. That author estimated the loss in different fields of the Bacska region as ranging from 5 to 60 per cent of the grain during 1916. Bakó (*4*) estimated that 50 per cent of the corn in the Bacska region was destroyed in 1917. In correspondence dated November 16, 1921, Joblonowski stated that the damage in Hungary from *P. nubilalis* had reached its culmination in 1919 and was now diminishing. He considers the loss to be unimportant during 1921.

During 1924 Mr. Babcock conducted observations in the principal corn-growing areas of Hungary, and his reports show that the corn borer caused serious damage to corn in restricted areas of the Great Plain of Hungary during that season, although it was not considered to be a favorable year for the insect. According to Mr. Babcock, appreciable damage occurred throughout the southern and central parts of the country, but that part of southern Hungary lying between Bekes and Novi Sad (including the contiguous areas of Rumania and Yugoslavia) was practically the only region observed, or reported, during 1924, where the corn borer caused serious interference with the growth of corn. Detailed studies of the actual losses caused by the corn borer in the cornfields of this region showed an average estimated loss of 23.9 per cent in 38 fields in the vicinity of Mezöhegyes, 18.9 per cent loss in 12 fields near Novi Sad, 18.4 per cent loss in 19 fields at Bankut, and losses ranging from 14.2 to 5.5 per cent in other districts of this region. A combination of fungus and borer injury was rather widespread in this region during 1924, and in the majority of instances where the grain had been injured by the borer the fungus developed and rendered the injury more serious. In seven fields of broomcorn examined near Mezöhegyes and Bankut, Mr. Babcock found that the stalk infestation ranged from 7.4 to 54.8 per cent, with a general average of 24.5 per cent and an average of 34.3 borers per 100 plants. An examination of five fields of hemp near Mezöhegyes showed an average stalk infestation of 14.5 per cent and an average of 17.4 borers per 100 plants. An examination of a 35-acre millet field at Mezöhegyes showed that 8.1 per cent of the plants were infested. In a 2-acre field of feterita at Bankut 3 per cent of the plants were infested.

Köppen (*35*) in 1880 first summarized the statements of various authors regarding *P. nubilalis* as a pest in Russia. He reported that the insect, though rather scarce, was well dispersed in that country. This same author refers to Widhalm, who reported that in 1879 the cornfields in the district of Odessa looked as though trampled by cattle and that millet was also injured in that district. Köppen also referred to Linderman, who mentioned severe damage to hemp in the government of Tula, and to Cancrin, who recorded severe injury to millet in the government of Jekaterinoslav. Kurjumov (*37*) in 1913 enumerated the damaged plants from Poltava as maize, millet, hemp, and hops. During the period from 1913 to 1920 there were many reports by Russian entomologists relative to the injury caused by *P. nubilalis* in Russia. Particular reference was made of serious damage to corn in Bessarabia during 1914 and 1915. Other reports from various localities in southern Russia mentioned injury (presumably to corn) varying from 20 to 90 per cent. Vassiliev (*69*) stated that in Kiev during 1914 Indian corn was injured more than millet and that the damage was confined chiefly to the stalk. According to this authority the insect was very injurious to corn in Jekaterinoslav during 1914, the grain being totally destroyed in some localities. Averin (*3*) recorded serious injury to maize in Charkov during 1915 and mentioned that in some cases 90 per cent of the stalks were infested. Uvarov (*68*) reports great damage to maize during 1916 and 1917 in Tiflis and Erivan. In correspondence dated December 20, 1921, D. N. Borodin asserted that according to his personal observation *P. nubilalis* is widely distributed in Russia, but is not a serious pest of corn, although it is injurious to millet, hemp, and hops. Dobrodeiv (*14*) records that it is found " as an injurious insect " in the following Provinces of European Russia: Minsk, Volhynia, Podolia, Kiev, Cherson, Poltava, Chernigov, Ekaterinoslov, Charkov, Kursk, Orel, Kaluga, Tula, Riazan, Tambov, Simbirsk, Voronej, Saratov, Don, and Kuban, and in Turkestan. Millet, maize, cotton, hemp, hops, and sunflowers are mentioned by this author as the principal economic crops attacked in Russia, but he does not give specific instances of damage except in the fields of the Voronej Agricultural Institute, where the infestation in different varieties of millet ranged from 14 to 63 per cent of the stems. Incidentally he mentions that the varieties of millet possessing a close growing habit were more susceptible, under Russian conditions, than varieties possessing " a branching widespread " habit.

In France the insect was first recorded as a pest by Duponchel (*15, p. 121, CCXVII, 4*), 1831, who mentioned it as being injurious to hops. Several French writers subsequently recorded *P. nubilalis* as a pest of maize, hops, and hemp, but no details concerning the extent of the injury are given. Robin and Laboulbène (*52*) reported damage to maize in the Department of the Aisne during a period of several years prior to and including 1879. No definite estimates of damage are given. The same authors mention that hemp was seriously injured in the Department of Lot-et-Garonne in 1878. P. Chretien (in correspondence dated May 20, 1919) mentions severe damage to corn in the Department of Aveyron during 1889. He records one cornfield of this district where nearly all of the stalks were infested and 75 per cent of the stalks bore atrophied ears. Schonfeld mentioned *P. nubilalis* as being very injurious to hops in Alsace during 1893. Vuillet (*72, p. 105*) reported in 1913 that the insect was injurious in the southwestern part of France and was the principal enemy of corn, yet the damage caused by it was small and often passed unnoticed. During this same year Marchal (*43*) reported that maize was seriously injured in the Department of Gers. In 1917 it was stated by Nöel that maize and hemp were attacked, but the locality and degree of injury were not indicated. Chretien (in correspondence) reported severe damage to corn in the Department of Basses-Pyrenees during 1918, and that 20 per cent of the stalks were broken over in some of the cornfields. Rives (*51*) observed severe damage to maize near Toulouse during 1919 and mentioned one field of maize in which 60 per cent of the " roots " were infested.

The first statement regarding damage by *P. nubilalis* in Italy appears to be that of Targioni-Tozzetti (*65, p. 28*) in 1884, who mentioned that hemp was attacked by the insect. In 1911 Silvestri (*19*, *p. 270*) reported it as damaging maize (Turkish wheat). During the summer of 1920 L. O. Howard, Chief of the Bureau of Entomology, made a general survey of the status of *P. nubilalis* in Italy and determined that the insect occurred throughout the entire Italian peninsula, but was not abundant. He found it principally in cornfields. K. W. Babcock made examinations of cornfields in the vicinity of Milan during the middle of July, 1924, and found thus early in the season an average stalk infestation of 38.6 per cent in 23 fields, with an average of 104.2 borers per 100 stalks. At Bergamo Mr. Babcock found an average stalk infestation of 40.6 per cent, with an average of 138 borers per 100 stalks. One field of early planted corn at Bergamo showed a stalk infestation of 83 per cent and an ear infestation of 14 per cent. In the fields around Florence the infestation was found to be very light. From notes contributed by W. R. Thompson and H. L. Parker, regarding the infestation in the cornfields of northern Italy during late June and early July, 1924, it is stated that in 5 fields near Turin the stalk infestation ranged from 20 to 49 per cent, in 4 fields at Novara the stalk infestation ranged from less than 1 to 82 per cent, and in 23 fields of the Bergamo region from 25 to 62 per cent of the stalks were infested. In the cornfields of the Pavia region an average of about 15 per cent of the stalks were infested, and in the region of Vicenza the infestation was very light. Doctor Thompson also reports that during some years the corn borer is said to be rather injurious to hemp in the region of Bologna.

In Bavaria *P. nubilalis* was recorded during 1880 as occurring in hops and hemp, but the injury was of no practical importance. Schonfeld, however, reports very severe injury to hops in Bavaria during 1886.

According to Schonfeld the hop fields of Bohemia were seriously injured by *P. nubilalis* during 1879 and 1880. Buzek, a schoolmaster of Rakonic, recorded that the entire hop yield was destroyed in some of the fields of the Rakonic district during 1879.

In Belgium *P. nubilalis* is reported by De Crombrugghe de Picquendael (*13*) as being abundant in the vicinity of Brussels, but no mention is made of injury to economic plants.

Briggs (*8*, *p. 39–40*) reported from the island of Guam that in 1919 fully 50 per cent of the corn crop was damaged in certain portions of the island. He also mentioned that grain sorghums and rice were attacked by the insect, and that 100 larvae were found in a single stalk of kafir corn.

DISTRIBUTION IN THE UNITED STATES

At the close of 1924 the European corn borer was known to be present in three large and two small separate areas of the United States (see map, fig. 1), comprising a total of 24,773 square miles. These figures relate to townships where the corn borer has actually been found and do not include certain townships which have been included in the quarantined area. The three large areas mentioned above are located (1) in eastern New England, (2) eastern New York and southwestern Vermont, and (3) in a narrow strip along the American shore of Lake Erie, comprising portions of the States of New York, Pennsylvania, Ohio, and Michigan. The two small areas of infestation are located (1) at Brooklyn, N. Y.; Staten Island, N. Y.; and Little Neck, N. Y.; and (2) in Nelson Township, Madison County, N. Y., respectively.

DISCOVERY AND DISTRIBUTION IN NEW ENGLAND

In 1917, when the presence of the European corn borer in the United States was first discovered, it was found to be distributed over an area of approximately 100 square miles located immediately north and northwest of Boston, Mass. According to Vinal (*70*), who first discovered the presence of the insect and secured its identification, the fields of early sweet corn in market gardens 10 or 12 miles inland were reported by the owners as having been seriously injured by this pest for three or four years prior to 1917. During this period, however, the depredator was not recognized as being a foreign pest. Judging by the intensity of the infestation in 1917 and by the size of the area infested at that time, as well as from the reports concerning the activity of the pest prior to 1917, Vinal was of the opinion that it had been imported about 1910, although realizing that this was only a conjecture. The investigations since 1917 have indicated that Vinal's estimate was probably very nearly correct, although the exact date is still unknown.

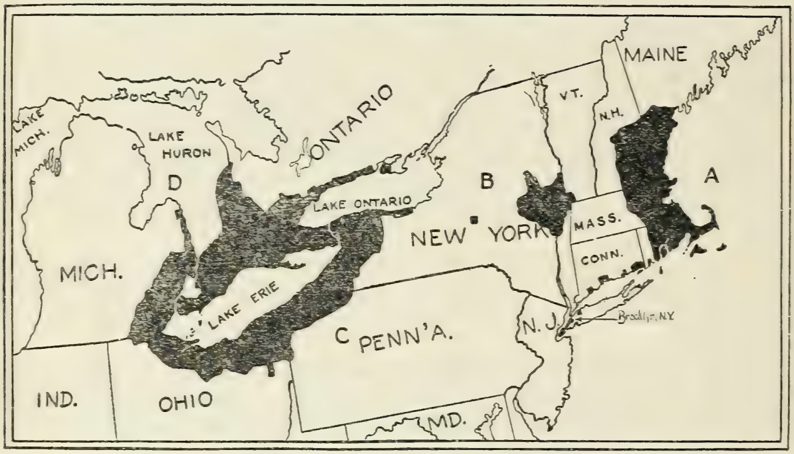

FIG. 1.—Map showing areas of European corn-borer infestation in North America as known January 1, 1925. A, New England area; B, eastern New York area in the vicinity of Schenectady and Albany; C, Lake Erie area, including western New York and a strip along the lake in Pennsylvania, Ohio, and Michigan; D, Canadian area of infestation. Small areas of infestation at Brooklyn, N. Y.; Staten Island, N. Y.; Little Neck, Long Island; and Nelson Township, N. Y., are also indicated

In 1916 specimens of dahlia stems infested by lepidopterous larvae were sent to the Massachusetts Agricultural Experiment Station from three localities near Boston, Mass. Adults were reared from this material, but their identity as *P. nubilalis* was not established until after adults had been reared from sweet corn by Vinal in 1917.

At the end of 1924 a total of 5,661 square miles was known to be infested by the European corn borer in this eastern New England area (see map, fig. 1), as shown by Mr. Worthley's field scouts, including eastern Massachusetts, the adjoining portion of New

Hampshire, southern Maine, seven townships in Rhode Island, and six scattered townships along the shore line of Connecticut. An infestation was also found during the summer of 1923 by scouts of the Federal Bureau of Entomology on Fishers Island, N. Y., which is located only about 7 miles offshore from the Connecticut infestation.

DISCOVERY AND DISTRIBUTION IN EASTERN NEW YORK

The insect was discovered during the latter part of January, 1919, at Scotia, N. Y., one of the suburbs of Schenectady, by F. V. Osterhoudt, in his garden at 223 Sanders Avenue. Mr. Osterhoudt had observed unfamiliar worms injuring the sweet corn in his garden during the previous summer, and when a popular article on the corn borer by R. H. Allen, of the Massachusetts State Department of Agriculture, appeared in the Country Gentleman the descriptions and illustrations led Mr. Osterhoudt to believe that this foreign pest was present in his corn. He sent specimens of the larva to C. R. Crosby, of Cornell University, who in turn referred them to the Lepidoptera specialist, W. T. M. Forbes. Doctor Forbes recognized in these the larvae of *P. nubilalis*, a determination which later was confirmed by Carl Heinrich,[4] of the Federal Bureau of Entomology. Professor Crosby immediately notified the Bureau of Entomology of this discovery on January 29, 1919.

Subsequent scouting by State and Federal men showed that a sparse but widespread infestation existed in the region surrounding Schenectady and portions of the Mohawk and Hudson River Valleys, together with adjacent territory. By the end of 1924, 72 townships and cities, containing 2,882 square miles, were known to be infested in this region. This area also included two adjoining townships containing 90 square miles in southwestern Vermont. (See map, fig. 1.)

DISCOVERY AND DISTRIBUTION IN THE LAKE ERIE SECTION

During the latter part of September, 1919, an infestation was discovered on the farm of Alfred Morrison at North Collins, Erie County, N. Y., about 25 miles south of Buffalo and a short distance from Lake Erie. Specimens of the larvae were collected by Mr. Morrison and sent to Cornell University, where they were identified as *P. nubilalis* by W. T. M. Forbes. This discovery was reported to the bureau by E. P. Felt, State entomologist of New York. Larvae and adults were later submitted to Carl Heinrich, who confirmed the determination.

In September, 1919, an infestation was also found on the farm of a Mr. Eagley of North Girard, Erie County, Pa., by D. M. DeLong, J. R. Eyer, and H. E. Bachus, of the Bureau of Plant Industry, Pennsylvania State Department of Agriculture. Specimens of the larvae were forwarded to Washington, through P. T. Barnes.

Subsequent scouting during 1919 and 1920 revealed that the infestation in the Buffalo section was very extensive, whereas the Girard infestation was very sparse and confined to a single field; in fact no specimens of *P. nubilalis* were found in the Pennsylvania area during 1920. The scouting during 1921 and 1922, however, disclosed that a sparse but extensive infestation had occurred in all the Pennsylvania towns bordering Lake Erie and adjacent thereto.

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[4] Mr. Heinrich has also been responsible for the determination of all other corn-borer material mentioned in this review of the occurrence of the pest in the United States to date.

During the summer of 1921 the insect was discovered (May 3, 1921) by scouts of the Federal Bureau of Entomology on the farm of Peter Sontz, East Point Road, Middle Bass Island, Ohio, in Lake Erie. This island is located about 7 miles from the Ohio shore. Subsequent scouting during the summer of 1921 revealed sparse infestations in most of the townships bordering Lake Erie in Ohio and Michigan, and also on the islands in the western end of the lake. The borers were more numerous on the islands at this time than on the mainland.

At the close of 1924 *P. nubilalis* was known to be present in practically all of the territory along the American shore of Lake Erie and extending a short distance inland. (See map, fig. 1.) This area includes 4,812 square miles in western New York; 1,999 square miles in northwestern Pennsylvania; 6,591 square miles in northern Ohio; and 2,828 square miles in southeastern Michigan, a total of 16,230 square miles in the Lake Erie section. The presence of the European corn borer in Pennsylvania, Ohio, and Michigan establishes the pest within a short distance of the large and extremely important corn-growing areas of the Middle West and also provides a possible means of natural dispersion southward because of the presence of the insect in the territory drained by the headwaters of the Ohio River.

DISCOVERY AND DISTRIBUTION IN OTHER AREAS

During the late summer of 1923 a small area of infestation was discovered in the Bay Ridge section of Brooklyn, N. Y., by scouts of the Federal Bureau of Entomology. Limited infestations were also found during 1924 on the northeastern side of Staten Island, N. Y., just across the channel from the Brooklyn area, and at Little Neck, Long Island. Many of the larvae found in this region were inhabiting weeds, and evidences were also present that the insect had undergone two generations in this area during 1923 and 1924. It is believed that this infestation is of great importance since rather extensive sweet corn growing areas are present on Long Island and in the near-by districts of New Jersey and Connecticut. The situation may become especially serious if two generations should continue to develop each year in this area.

A single specimen of *P. nubilalis* pupa was discovered during July, 1923, in Nelson Township, Madison County, N. Y., by W. L. Miles, a former employee of the Bureau of Entomology. This area is located about 50 miles west of the main eastern New York area. A few specimens of the larvae were found later in a near-by field by a scout of the Federal Bureau of Entomology. Only two infested fields were found in this area.

Extensive scouting operations have been maintained during the period from 1921 to 1924 in the territory surrounding and adjacent to the infested areas of New England, New York, Pennsylvania, Ohio, and Michigan, as well as along the main lines of travel, river valleys, water routes, the vicinity of broom factories, and other susceptible localities in those States. Scouting operations have also included field examinations in susceptible localities in the territory east of and including the Mississippi River basin States, as well as in Texas, New Mexico, and Arizona. Particular attention has been given localities where imported broomcorn was known to have been received, as well as to sections producing field corn, sweet corn, and broomcorn. Special scrutiny has been given the territory adjacent to ocean and river ports and railroad centers and along the main railroad, highway, and water routes.

DISTRIBUTION IN THE DOMINION OF CANADA

During August, 1920, the Canadian authorities reported the discovery of an infestation by the European corn borer in Welland County, Ontario, along the Niagara River immediately opposite the western New York area of infestation, and another larger and more heavily infested area along the Canadian shore of Lake Erie, with its apparent center near St. Thomas, Ontario.

At the close of 1924 the pest was present in an area of approximately 18,000 square miles, comprising the entire southern Ontario peninsula bordering Lake Erie and including Pelee Island in the lake. The area of infestation in Ontario was practically continuous with the area of infestation on the United States side of Lake Erie. (See map, fig. 1.)

The character of the infestation in Middlesex and Elgin Counties, Ontario, was more severe than in any of the areas in the United States, with the exception of that existing in New England, and, according to Crawford and Spencer (*12*), very severe losses occurred to flint field corn and to sweet corn, whereas dent field corn in general suffered to a lesser extent.

The presence of this large and severely infested area directly across Lake Erie from American territory constitutes a source of possible further dispersion to the lake regions of New York, Pennsylvania, Ohio, and Michigan, through both the natural and artificial spread of the insect. The severe character of the infestation in part of Ontario is also indicative of conditions which may be expected eventually to develop on the American side of the lake, as the climatic and agricultural conditions are similar.

PROBABLE MANNER OF IMPORTATION

The precise manner in which the European corn borer gained entrance to the United States is not definitely known, but as a result of investigations conducted since its original discovery in New England, it is believed that broomcorn which was imported for manufacturing purposes from Hungary or Italy during the period from 1909 to 1914 was the probable carrier (*58*). At this time the conditions of the trade were such that unusually large quantities of broomcorn were imported, the report of the Bureau of Foreign and Domestic Commerce, Department of Commerce, showing that at least 12,000 tons were received during this period. Broomcorn is known to be commonly infested by *P. nubilalis* in both Hungary and Italy, where much of this material originated. The inspection service was not authorized by law until 1913, and therefore it was not possible to intercept this material upon its arrival at the ports of entry.

Parts of these importations were received at broom factories located at Everett, Mass., near the apparent center of the original New England infestation, and at Amsterdam, N. Y., near the apparent center of the eastern New York infestation. The remainder of these importations were traced to many different parts of the United States, but subsequent extensive scouting in localities where they were known to have been received has failed to reveal any additional infestations.

Raw hemp was formerly believed to be the most likely medium through which the European corn borer gained entrance to this country, but in the light of our present knowledge this theory appears untenable, and broomcorn appears to have been the probable vehicle in which it entered America.

The supposition that *P. nubilalis* was originally imported in broomcorn received an apparent confirmation during February and March, 1920, in April, 1922, and again in March, 1923, when commercial shipments of broomcorn from Hungary and Italy were intercepted by inspectors of the Federal Horticultural Board at the port of New York and were found to contain many living larvae of the pest. This broomcorn was in the raw, or unmanufactured state, and consisted of about 30 inches of the upper part of the broomcorn plant, including the "hurls" or that portion usually incorporated in ordinary house brooms and the upper part of the stalk or "butt." Corn-borer larvae were found throughout the length of the "butt" proper, and also within the extreme upper tip of the terminal internode beyond the point where the "hurls" or broom splints are attached. (Fig. 2.) During March, 1923, the inspectors also intercepted living larvae of *P. nubilalis* in stalks of broomcorn in passengers' baggage arriving at New York from Italy and Germany.

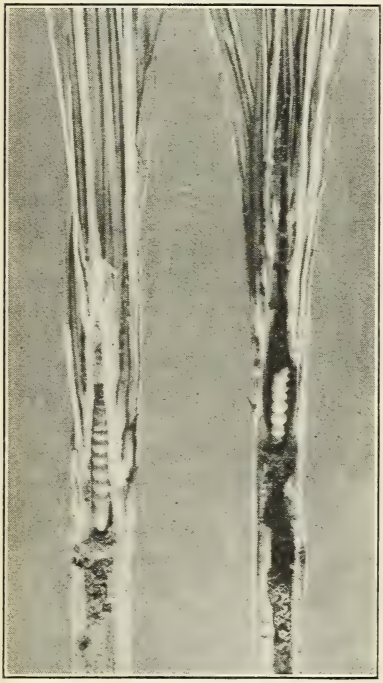

FIG. 2.—Broomcorn butts sectioned to show typical injury by European corn borer and borers in position at base of hurls. Medford, Mass., November, 1921. Broomcorn infested in a similar manner, originating in Hungary and Italy, has been intercepted at the port of New York by inspectors of the Federal Horticultural Board

An investigation of the broom industry indicated that the customary methods of handling raw broomcorn afforded an opportunity for the dispersion of the insect if contained within the material. The fact was determined that the foreign broomcorn, previously mentioned as having been received at Everett, Mass., was kept in storage for several years before being used, thus giving every opportunity for any larvae contained therein to complete their development and emerge as moths. During the process of manufacture a section several inches long often is removed from the base of the "butt" and discarded as refuse. Infested refuse of this character, unless promptly destroyed, may become a source of danger, especially when dumped along the banks of water courses. The original infestation in eastern New York, along the Mohawk River, is believed to be directly traceable to infested refuse from the broom factory at Amsterdam, previously mentioned as having received foreign importations. It was also determined that occasionally the raw material is made into large brooms, for stable or other rough use, without any preliminary process or manufacture, and in such a manner that opportunity is afforded for the dispersion of any corn-borer larvae that might be contained therein. Moreover, it was determined that the sulphuring and other processes undergone by the broomcorn during manufacture was not always sufficient to insure the destruction of all the larvae contained therein. Consequently there is a possibility that some kinds of brooms manufactured from infested material may serve to disseminate the insect.

Concerning the infestations on the islands and along the shore of Lake Erie in Michigan, Ohio, and Pennsylvania, it is believed that they may have originated from the intensely infested area directly across the lake in the Province of Ontario. The history and intensity of this infestation near Saint Thomas and Port Stanley, Ontario, indicate it as probably the oldest colony of the pest in this region. The infestation in western New York possibly may have originated from this same source, although its origin is more obscure.

The method of dispersion from Ontario may have been by flight of the moths or by drift of infested plant material in the waters of Lake Erie. A study of the wind and water currents in the Lake Erie region, in relation to the known habits of the insect, show the possibility of such dispersion through either of these agencies, as will be discussed in greater detail in another part of this bulletin.

The origin of the Ontario infestation is thought by McLaine (*41*) to be possibly traceable to large importations of broomcorn into Elgin and Middlesex Counties from central Europe during the period from 1909 to 1910, although no conclusive evidence has been obtained upon this point.

HOST PLANTS

HOST PLANTS IN FOREIGN LANDS

According to foreign authorities the most common economic host plants of *P. nubilalis* in the Old World are corn (or maize), hops, millet (*Panicum miliaceum* L.), hemp (*Cannabis sativa* L.), and broomcorn. Indian corn, or maize, however, appears to be the preferred host of the species in the Old World and is usually mentioned as being more severely injured than any of its other hosts. Hop is considered to be second in importance as a host of the species, while millet, hemp, and broomcorn are commonly attacked when grown within the range of distribution of the insect. In regions where for climatic reasons corn can not successfully be grown, particularly along the northern limit of distribution of the insect, it is able to subsist upon other plants, notably millet and hops, thus demonstrating that in its native habitat the species is not dependent upon corn. Owing to its status as a pest of millet and hops it is frequently mentioned in foreign literature as the "millet borer" and the "hop-vine borer." The original host of the species is a matter of conjecture, but it is believed by different authorities to have been either the hop plant or some one of the larger Asiatic or European grasses or grasslike plants. The fact that corn is of American origin precludes the possibility that this plant was the original host of *P. nubilalis.* The insect was first found in middle Europe living in millet (*P. miliaceum*) and in maize. Judging from the known history and habits of the insect and the history of its more susceptible hosts, there appear to be good reasons for considering wild hop as the original host. Hop affords excellent opportunities for the survival of the insect, since it is a perennial, whereas millet and hemp, two other possible original hosts, are annuals. Millet is said to derive its origin from Egypt and Arabia and hemp from Dauria and Siberia, but the hop is indigenous to Europe.[5]

De Crombrugghe de Picquendaele (*13*) records that in Belgium, mugwort (*Artemisia vulgaris* L.) is the chief host plant. P. Chretien, curator of the National Museum of Natural History at Paris, also states in correspondence that this plant is the favorite host in northern France. This and allied species are mentioned as hosts by several other writers. Pigweed (*Amaranthus retroflexus* L.) is recorded as a frequent host by Jablonowski (*29*) and has been found commonly infested near Hyères, France, by W. R. Thompson, of the Bureau of Entomology.

Foreign literature contains reference to a great variety of occasional or minor host plants, including oats (*49*), barley (*49*), cotton (*69*), rice (*8, pp. 39–40*), kafir (*8, pp. 39–40*), bean pods (*52*), sunflower (*36*), mustard (*36*), barnyard grass (*Echinochloa crus-galli* (L.) Beauv.) (*33*), giant reed (*Arundo donax* L.) (*47*), fuller's teasel (*Dipsacus fullonum* L.) (*29*), green foxtail (*Chaetochloa viridis* (L.) Scrib.) (*52*), stinging nettle (*Urtica urens* L.) (*50, p. 16*), thistles (*Cirsium or Carduus* spp.) (*29*), ploughman's spikenard (*Inula conyza* D. C.) (*13*), stiff inula (*Inula squarrosa* L.) (*72, p. 106*), and common reed (*Phragmites communis* Trin.) (*13*). K. W. Babcock recorded an infestation in feterita at Mezöhegyes, Hungary.

Professor Chretien, in correspondence, mentioned thistle (*Carduus tenuiflorus* Curtis) and garden orach (*Atriplex hortensis* L.) as hosts in northern France. W. R. Thompson, in correspondence, has recorded bean pods, tomato fruits, tumble weed (*Amaranthus graecizans* L.), wood amaranth (*Amaranthus silvestris* Desf.), and *Picris spinulosa* Guss. as hosts in the vicinity of Hyères, France, and he observed eggs on dock (*Rumex* sp.) in the Paris region. From Ekaterinoslaw, Russia (*46*), it is mentioned as a "market garden pest." Jablonowski [5] has cited an instance where grapevines (*Vitis vinifera* L.) were heavily infested by *P. nubilalis* larvae which had migrated from near-by cornstalks. The species has also been found in oak galls (*52*). The adults have been observed upon heather (*32*) and upon virgin's bower (*Clematis vitalba* L.) (*29*), but there is no record of the larvae being found in these plants. Sand (*53, p. 121*) and Vuillet (*72*) have recorded the larvae from several of the Gramineae.

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[5] See footnote 1.

It is probable that some of the plants recorded as hosts of *P. nubilalis* in the Old World serve primarily as shelter plants rather than as food, a condition which is known to prevail in the infested areas of America.

HOST PLANTS IN AMERICA

In general, corn appears to be the preferred host of the European corn borer in America and is more seriously injured by the insect than any other cultivated crop attacked. This includes sweet corn, field corn (both dent and flint), and pop corn. In the heavily infested area of eastern New England the pest also attacks and frequently causes serious injury to a great variety of other economic plants, including several of the field crops, vegetables, flowers, and

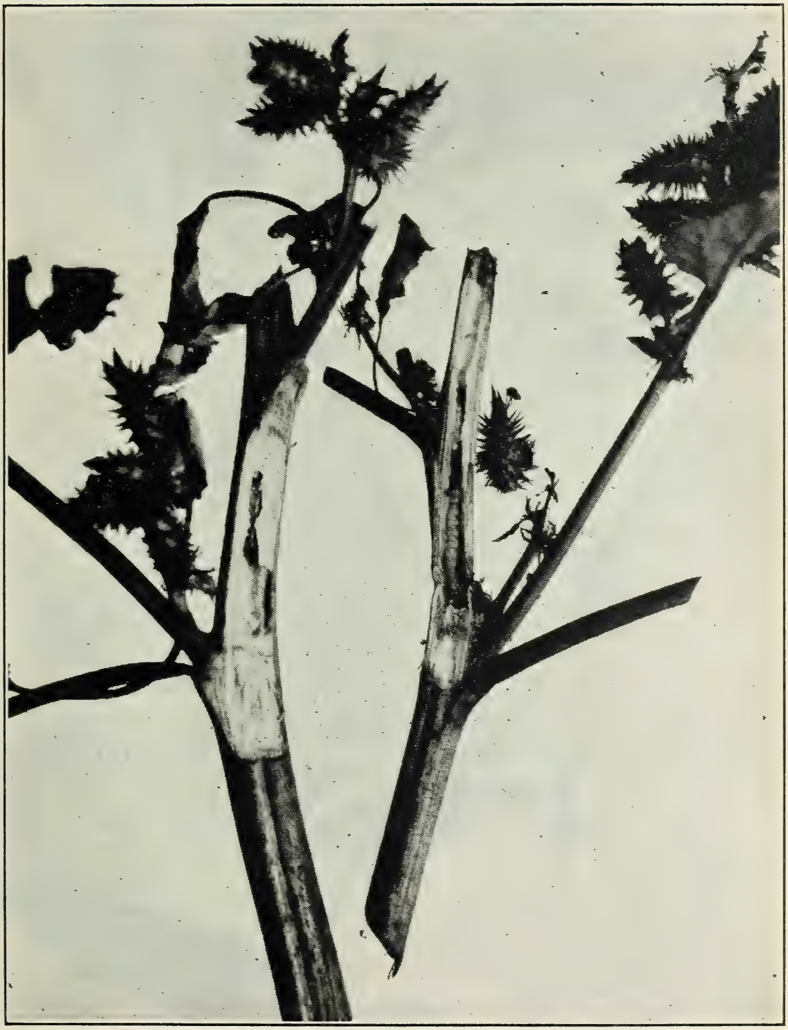

FIG. 3.—Cocklebur (*Xanthium* sp.), a susceptible weed host of the European corn borer

grasses. The infestation in crops, other than corn, is especially likely to occur (1) when corn is growing near by, (2) when the infested crop remnants and weeds from previous crops on the same or adjacent areas have not been destroyed, and (3) when susceptible weeds are growing in the field or in its immediate vicinity. Many weeds are included as hosts, thus serving to complicate the control of the pest and aiding in its multiplication and dispersion. Occasionally in certain fields some of these weeds, notably cocklebur (*Xanthium* spp., fig. 3), barnyard grass (*Echinochloa crus-galli* (L.) Beauv.), and smartweed (*Polygonum* spp., fig. 4), appear to be preferred as hosts rather than corn.

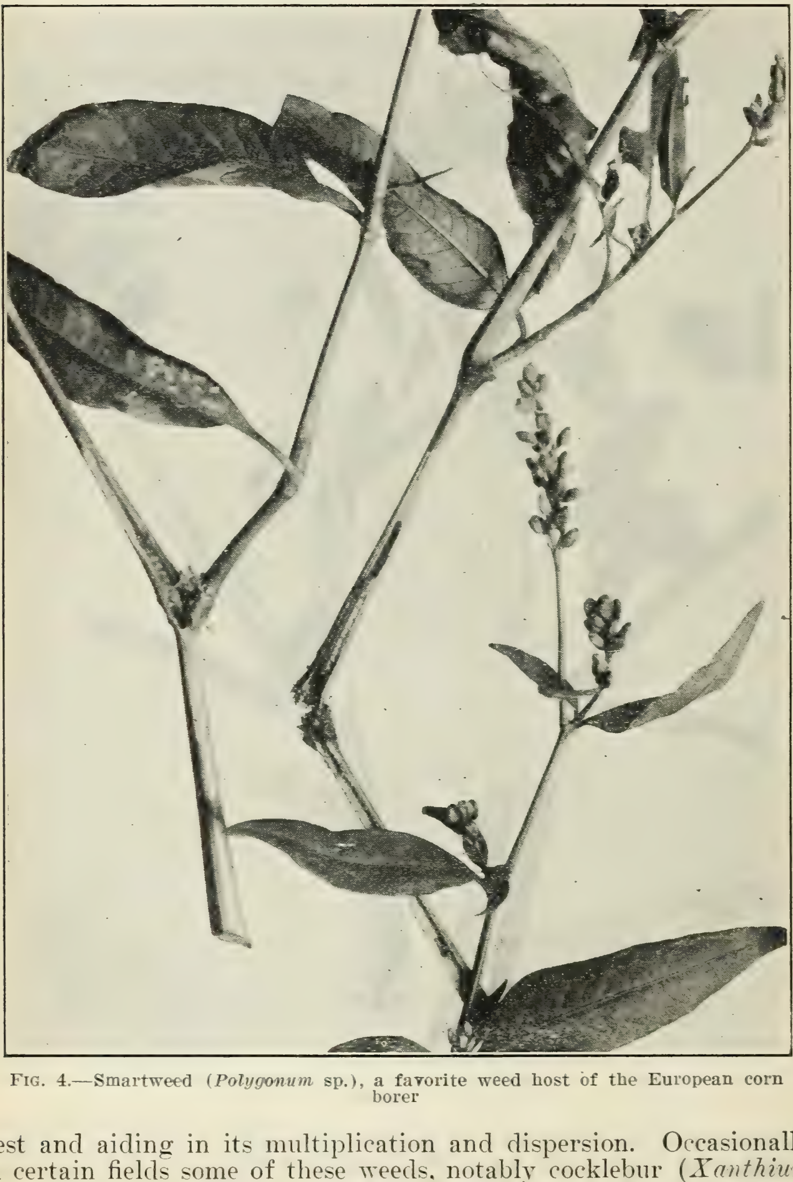

FIG. 4.—Smartweed (*Polygonum* sp.), a favorite weed host of the European corn borer

In some cases it seems that the species of plant selected as food or as shelter depends more upon its location with reference to other heavily infested plants or plant material than upon its character as a plant. The protection afforded to gravid females also appears to be a determining factor in some instances, since eggs are deposited freely upon certain large-leaved plants, rhubarb for example, which afford protection to the females during the day. Moreover, some plants in which the larvae are not known to feed are occasionally utilized for egg deposition, as will be shown in this discussion.

In New York, Pennsylvania, Ohio, and Michigan, and in Ontario, the infestation to date has been confined mostly to corn, with comparatively slight infestation in the more susceptible weeds. Occasional borers also have been found in some of the economic plants in the Lake Erie region and in Ontario. During 1923 and again in 1924 two commercial fields of broomcorn in western New York sustained infestations which were nearly equal to those of field corn in the vicinity. Probably the intensity and variety of infestation in susceptible weeds, vegetables, field crops, and flowering plants eventually will increase in these areas if the insect should become more numerous. It is possible also that the comparatively restricted list of host plants in these areas, as compared to New England, may be influenced by the fact that in New England two generations usually occur annually, whereas in the more western areas and in Ontario only one generation has yet been observed, except in favorable seasons when a few individuals of a second generation have developed. Under two-generation conditions the insect begins its feeding activity much earlier in the season than where but one generation occurs, and continues feeding actively throughout a longer total period for the season. Therefore it is able to use as hosts during the early part of the season, and again during the late season, many plants which are not available in an attractive or susceptible stage of growth during the period when the single-generation adults and larvae are most active.

NEW ENGLAND

In this section, up to January 1, 1924, the European corn borer has been found inhabiting a total of 215 different species and varieties of plants, some of which apparently serve primarily as shelter rather than food for the borers.

The relative degree of susceptibility of these host plants to *P. nubilalis*, and the parts attacked, are shown in the following list (Table 1) compiled for the New England area. In genera where two or more species were found to be hosts of *P. nubilalis*, usually only the generic name is listed.

TABLE 1.—*Classified list of P. nubilalis host plants*

CLASS 1.—PLANTS SEVERELY ATTACKED

Names of plants	Parts attacked
Barnyard grass (*Echinochloa crus-galli* (L.) Beauv.)	Stems.
Beggar-ticks (*Bidens* spp.) [1]	Do
Broomcorn (*Holcus sorghum* L.) [2]	Stalks.
Cocklebur (*Xanthium* spp.) [1]	Stems, burs.
Corn (*Zea mays* L.) (flint, dent, pop, sweet) [1]	All parts except fibrous roots.
Dahlia (*Dahlia* spp.)	Stalks, flowers.
Dock (*Rumex* spp.) [1]	Stems.
False ragweed (*Iva xanthifolia* Nutt.) [2]	Do.
Grain sorghum (*Holcus sorghum* L.) (feterita, hegari, milo, kafir) [1, 2]	Stalks, seed heads.
Hemp (*Cannabis sativa* L.) [2]	Do.
Japanese hop (*Humulus japonicus* Sieb. & Zucc.)	Stems.
Japanese millet (*Echinochloa crus-galli edulis* Hitchc.) [2]	Do.
Pigweed (*Amaranthus retroflexus* L.)	Stems, flowers.
Prince's plume (*Polygonum orientale* L.)	Stalks, flower stems.
Ragweed (*Ambrosia* spp.) [1]	Stems.
Rhubarb (*Rheum rhaponticum* L.)	Leaf stalks.
Smartweed, Knotweed (*Polygonum* spp.) [1]	Stems.
Wormseed (*Chenopodium ambrosioides* L.)	Do.

CLASS 2.—PLANTS FREQUENTLY ATTACKED

Barley (*Hordeum vulgare* L.) [2]	Stems
Bean (*Phaseolus* spp.) (kidney, lima, scarlet runner) [1]	Stalks, pods, seeds.
Beet (*Beta vulgaris crassa* Alef.)	Leaf stalks, rarely beet roots.
Broomcorn millet (*Panicum miliaceum* L.) [2]	Stems.
Burdock (*Arctium* spp.) [1]	Do.
Celery (*Celeri graveolens* (L.) Britton)	Leaf stalks.
China aster (*Callistemma chinense*)	Stalks, flower stems.
Chrysanthemum (*Chrysanthemum* spp.)	Stalks, flowers.
Cotton (*Gossypium hirsutum* L.) [2]	Stalks, bolls.
Cowpea (*Vigna sinensis* (L.) Endl.) [2]	Stalks, pods.
Horseweed (*Erigeron canadensis* L.)	Stems.
Japanese fleece flower (*Polygonum sieboldii* De Vriese)	Do.
Jimson weed (*Datura* spp.) [1]	Stems, seed pods.
Pepper (*Capsicum annum* L.)	Stalks, fruit.
Potato (*Solanum tuberosum* L.)	Stalks.
Sorgo (*Holcus sorghum* L.) [2]	Do.
Sunflower (*Helianthus annuus* L.)	Do.
Swiss chard (*Beta vulgaris cicla* Moq.)	Leaf stalks.
Tansy (*Tanacetum vulgare* L.)	Stems.
Teosinte (*Euchlaena mexicana* Schrad.) [2]	Stems, leaf blades.
Wormwood (*Artemisia* spp.) [1]	Stems.
Zinnia (*Zinnia elegans* Jacq.)	Stalks, flower stems.

CLASS 3.—PLANTS OCCASIONALLY ATTACKED

Aster (*Aster* spp.)[1]	Stems.
Boltonia (*Boltonia asteroides* (L.) L'Her.)	Stalks.
Bread grass (*Panicum* spp.)[1]	Stems.
Buckwheat (*Fagopyrum vulgare* Hill)[2]	Do.
Calendula (*Calendula officinalis* L.)	Stalks, flower stems.
Canna (*Canna* spp.)	Stalks, leaves, flowers.
Cockscomb, common (*Celosia cristata* L.)[2]	Stems, flowers.
Cockscomb, feather (*Celosia argentea* L.)[2]	Do.
Coleus (*Coleus* spp.)	Stems.
Cosmos (*Cosmos bipinnatus* Cav.)	Stalks.
Crab grass (*Syntherisma sanguinalis* (L) Dulac)	Stems.
Eggplant (*Solanum melongena* L.)	Fruit.
Feverfew (*Chrysanthemum parthenium* (L.) Bernh.)[2]	Stalks, flower stems.
Fireweed (*Erechtites hieracifolia* (L.) Raf.)	Stalks.
Galinsoga (*Galinsoga* sp.)	Stems.
Geranium (*Pelargonium hortorum*)	Stalks.
Gladiolus (*Gladiolus* spp.)	Stalks, flowers.
Golden Glow (Hort. var. of *Rudbeckia laciniata* L.)	Stalks, flower stems.
Goldenrod (*Solidago* spp.)[1]	Stems.
Hollyhock (*Althaea rosea* Cav.)	Stalks, leaf stems.
Hop, common (*Humulus lupulus* L.)[2]	Stems.
Jerusalem artichoke (*Helianthus tuberosus* L.)	Stalks.
Lamb's quarters (*Chenopodium album* L.)	Stems.
Mallow (*Malva* spp.)[1]	Do.
Mangel (*Beta vulgaris crassa* Alef.)[2]	Leaf stalks.
Motherwort (*Leonurus cardiaca* L.)	Stems.
Mustard (*Brassica* spp.)[1]	Do.

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[1] Two or more species or varieties are grouped under this common name. The names of these species will be furnished to interested persons.

[2] Plants occurring rarely or grown only in the experimental fields. These plants are classified according to their susceptibility rather than the frequency in which they are found infested.

TABLE 1.—*Classified list of P. nubilalis host plants*—Continued

CLASS 3.—PLANTS OCCASIONALLY ATTACKED—Continued

Names of plants	Parts attacked
Nettle (*Urtica lyallii* Wats.)	Stems.
Oat (*Avena sativa* L.)	Do.
Orach (*Atriplex* sp.)	Do.
Prickly lettuce, Wild L. (*Lactuca* sp.)	Do.
Purslane (*Portulaca oleracea* L.)	Do.
Salvia, scarlet sage (*Salvia splendens* Ker-Gawl.)	Stalks, flower stems.
Sow thistle (*Sonchus* spp.)[1]	Stems.
Spinach (*Spinacia oleracea* L.)	Leaf stems.
Strawflower (*Helichrysum bracteatum* Andr.)[2]	Stalks, flower stems.
Thistle (*Cirsium* spp.)[1]	Stems.
Tomato (*Lycopersicon esculentum* Mill.)	Stalks, fruit.
Velvetleaf (*Abutilon theophrasti* Medic.)[2]	Stems.
Yarrow (*Achillea millefolium* L.)	Do.

CLASS 4.—PLANTS RARELY ATTACKED

Ageratum (*Ageratum houstonianum* Mill.)	Stalks, flower stems.
Apple-of-Peru (*Nicandra physalodes* (L.) Pers.)[2]	Stems.
Ailanthus (*Ailanthus* sp.)[2]	Leaf stems.
Apple (*Pyrus malus* L.)	Fruit (wind-falls).
Asparagus (*Asparagus officinalis* L.)[3]	Mature stalks.
Balsam (*Impatiens balsamina* L.)	Stems.
Blackberry (*Rubus* sp.)[3]	Canes.
Black-eyed Susan (*Rudbeckia hirta* L.)	Stems.
Blister cress (*Cherinia cheiranthoides* (L.) Link)	Do.
Blue vervain (*Verbena hastata* L.)	Do.
Cabbage (*Brassica oleracea capitata* L.)[3]	Stalks.
California poppy (*Eschscholtzia* sp.)	Stems.
Candytuft (*Iberis* sp.)	Do.
Cardoon (*Cynara cardunculus* L.)[2]	Leaf stalks.
Catnip (*Nepeta cataria* L.)[3]	Stems.
Cat-tail (*Typha latifolia* L.)	Do.
Cauliflower (*Brassica oleracea botrytis* DC.)	Leaf stalks.
Celandine (*Chelidonium majus* L.)[3]	Stems.
Chicory (*Cichorium intybus* L.)	Do.
Clover, Alsike (*Trifolium hybridum* L.)	Do.
Coltsfoot (*Tussilago farfara* L.)[2]	Leaf stalks.
Cornflower (*Centaurea cyanus* L.)	Stems.
Cucumber (*Cucumis sativus* L.)	Fruit.
Cup-plant (*Silphium perfoliatum* L.)[2]	Stems.
Daisy, ox-eye (*Chrysanthemum leucanthemum* L.)	Flower stems.
Elder (*Sambucus canadensis* L.)[3]	Branches.
Endive (*Cichorium endivia* L.)[2], [3]	Stalks, seed heads.
Evening primrose (*Oenothera* sp.)[3]	Stems.
False dragon head (*Physostegia virginiana* (L.) Benth.)[2]	Stems.
Fleabane (*Erigeron annuus* (L.) Pers.)	Do.
Foxtail, green (*Chaetochloa viridis* (L.) Scribn.)	Stems, seed heads.
Foxtail, yellow (*Chaetochloa lutescens* (Weigel) Stuntz)	Do.
Grape, Concord (Hort. var. of *Vitis labrusca* L.)	Stems, fruit.
Groundsel, common (*Senecio vulgaris* L.)[2]	Stems.
Hedge mustard (*Sisymbrium* sp.)[3]	Do.
Heliotrope (*Heliotropium peruvianum* L.)	Flower stems.
Horsetail (*Equisetum* sp.)	Stems.
Jerusalem cherry, false (*Solanum capsicastrum* Link)	Fruit.
Jewelweed (*Impatiens biflora* Walt.)	Stems.
Joe-pye weed (*Eupatorium* sp.)	Do.
Johnson grass (*Holcus halepensis* L.)[2]	Do.
Knapweed (*Centaurea nigra* L.)[3]	Do.
Locust, common (*Robinia pseudoacacia* L.)	Sprouts.
Love-lies-bleeding (*Amaranthus caudatus* L.)[2]	Stems.
Mallow (*Hibiscus* sp.)[3]	Do.
Maple-leaf goosefoot (*Chenopodium hybridum* L.)[2]	Do.
Marigold, Aztec or African (*Tagetes erecta* L.)	Stalks.
Mayweed (*Anthemis cotula* L.)	Stems.
Mignonette (*Reseda odorata L.*)	Stalks
Milkweed (*Asclepias* spp.)[3]	Stems.
Millet, golden wonder (*Chaetochloa italica germanica* (Mill.) Farwell)[2]	Do.
Millet, Hungarian (*Chaetochloa italica* (L.) Scribn.)[2]	Do.
Millet, pearl (*Pennisetum glaucum* (L.) R. Br.)[2]	Do.
Mint (*Mentha* spp.)[1]	Stalks.
Night-flowering catchfly (*Silene noctiflora* L.)[2]	Stems.
Nightshade, black (*Solanum nigrum* L.)	Do.
Okra or gumbo (*Hibiscus esculentus* L.)[2]	Stalks.
Oswego bee balm (*Monarda didyma* L.)[2], [3]	Stalks, flower stems.
Pansy (*Viola tricolor* L.)	Stems.
Parsnip (*Pastinaca sativa* L.)	Stalks.
Peanut (*Arachis hypogaea* L.)[2]	Stems.

[1] Two or more species or varieties are grouped under this common name. The names of these species will be furnished to interested persons.

[2] Plants occurring rarely or grown only in the experimental fields. These plants are classified according to their susceptibility rather than the frequency in which they are found infested.

[3] Plants which apparently serve only as shelter for the larvae.

TABLE 1.—*Classified list of P. nubilalis host plants*—Continued

CLASS 4.—PLANTS RARELY ATTACKED—Continued

Names of plants	Parts attacked
Pear (*Pyrus communis* L.)	Fruit.
Pokeberry (*Phytolacca americana* L.)[2]	Stems.
Portulaca (*Portulaca grandiflora* Hook)	Do.
Prince's feather (*Amaranthus hypochondriachus* L.)[2]	Stalks, flower heads.
Rape (*Brassica napus* L.)[2]	Leaf stalks.
Radish, wild (*Raphanus raphanisrum* L.)	Stalks.
Raspberry (*Rubus* spp.)[3]	Canes.
Red clover (*Trifolium pratense* L.)[3]	Stems.
Rose (*Rosa* sp.)	Do.
Rose loosetrife (*Lythrum* sp.)[2], [3]	Do.
Rough cinque foil (*Potentilla monspeliensis* L.)[2]	Do.
Scabiosa (*Scabiosa atropurpurea* L.)	Do.
Shepherd's purse (*Bursa bursa-pastoris* (L.) Weber)[3]	Do.
Sorrel, field or sheep (*Rumex acetosella* L.)	Do.
Soy bean (*Soja max* (L.) Piper)[2]	Stalks.
Spiderflower (*Cleome spinosa* L.)	Stems.
Squash (*Cucurbita maxima* Duchesne)	Leaf, stalks, fruit.
Stevia (*Piqueria trinervia* Cav.)	Stems.
Sudan grass (*Holcus sorghum sudanensis* (Piper) Hitchc.)[2]	Do.
Sugar beet (Hort. var. of *Beta vulgaris* L.)	Leaf stalks.
Sumac, smooth (*Rhus glabra* L.)[3]	Stems, leaf petioles.
Summer cypress (*Kochia trichophylla* Stapf.)	Stems.
Summer squash (*Cucurbita* sp.)[2]	Leaf stalks, fruit.
Sweet clover, white (*Melilotus alba* Desr.)	Stems.
Sweet sultan (*Centaurea moschata* L.)	Do.
Timothy (*Phleum pratense* L.)	Stems, seed heads.
Tobacco (*Nicotiana tabacum* L.)[2]	Stalks.
Turnip (*Brassica rapa* L.)	Leaf stems.
Water hemlock (*Cicuta maculata* L.)[3]	Stalks.
Wheat (*Triticum sativum* L.)	Stems.

[2] Plants occurring rarely or grown only in the experimental fields. These plants are classified according to their susceptibility rather than the frequency in which they are found infested.

[3] Plants which apparently serve only as shelter for the larvae.

The insect has been reared from egg to adult in many of the plants in the first three classes, while eggs, larvae, and pupae have been collected from the majority of them in the field. Egg clusters have also been found in the field on dandelion (*Leontodon* spp.), horseradish (*Radicula armoracia*), lettuce (*Lactuca sativa*), oxalis (*Oxalis* spp.), plantain (*Plantago* sp.), and rye (*Secale cereale*), although the larvae are not known to feed on these plants. Under experimental conditions the borer has succeeded in competing its life history upon bluegrass (*Poa pratensis* L.). Sufficient evidence, therefore, has been accumulated to show that the species is capable of completing its development and existing independently of corn, a fact which is substantiated by the status of the borer as a pest of hops, millet, hemp, and other crops in the Old World, and by its distribution in regions beyond the climatic limits where corn may be grown.

EASTERN NEW YORK

The infestation in eastern New York has been confined practically to corn. Occasional specimens, however, have been found in giant ragweed, green foxtail, smartweed, beggar-ticks (fig. 5), pigweed, and cocklebur.[7]

LAKE ERIE REGION

Although corn is infested to a greater extent than any other plant throughout the Lake Erie region, a light infestation (to January 1, 1924) has been recorded in western New York, in the following weeds: Barnyard grass, beggar-ticks, common burdock, cocklebur, curled or yellow dock, green foxtail, lamb's quarters, bread grass, pigweed, common ragweed, smartweed, and common thistle.[7] Here, occasional borers have also been found in the stems of soy bean, sorghum,[8] Japanese millet,[8] broom corn millet or proso, buckwheat, rhubarb,[8] kidney or wax bean,[8] milo[8] tomato stem and fruit, potato, dahlia,[8] and cosmos.[8] During 1923 two fields (a total of 12 acres) of broom corn grown at Irving, N. Y., showed stalk infestation of 12.7 and 15.8 per cent respectively. In Ohio, according to reports of F. W. Poos to December 31, 1924, occasional borers have been found in the following host plants in addition to corn: Smartweed, pigweed, cocklebur, ragweed, water hemp (*Acnida tuberculata* Moq.), beggar-ticks, old witch grass,[7] and barley.

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[7] For scientific names see classified list in Table 1.

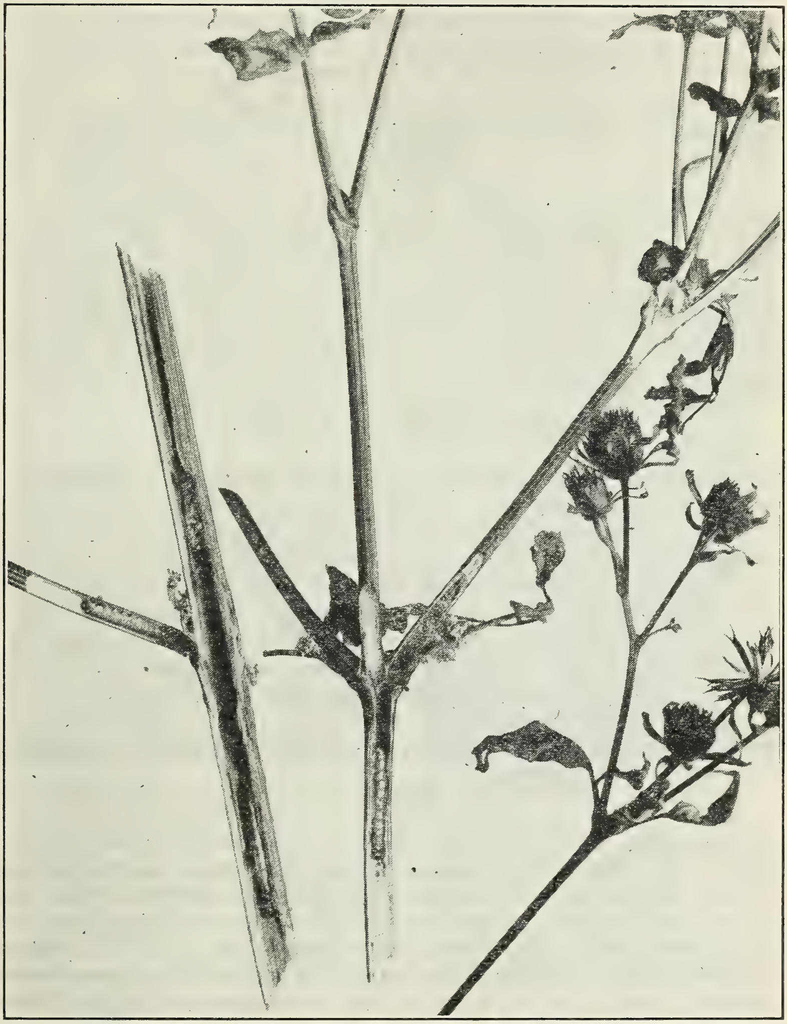

FIG. 5.—Beggar ticks (*Bidens* sp.) showing typical injury by the European corn borer

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[8] Found infested in experimental plats only.

CANADA

According to Crawford and Spencer (*12*, *60*), the following cultivated crops and flowers, in addition to corn, were found to be infested in Ontario: Dahlia, geranium, aster, golden glow, beets, mangels, tomatoes (fruit), beans, oats, squash vines, broomcorn, Sudan grass, Early Amber sorghum, Hungarian grass, Mann's Wonder sorghum, white clover, and red raspberry. The following weed hosts are also recorded by the same investigators: Barnyard grass (*Echinochloa crus-galli* (L.) Beauv.), redroot pigweed (*Amaranthus retroflexus* L.), yellow foxtail (*Chaetochloa lutescens* (Weigel) Stuntz); lamb's quarters (*Chenopodium album* L.), Russian thistle (*Salsola pestifer* Nels., var. *tenuifolia* G. F. W. Mey.), green foxtail (*Chaetochloa viridis* (L.) Scribn.), lady's thumb (*Polygonum persicaria* L.), wild buckwheat (*Polygonum convolvulus* L.), ground cherry (*Physalis heterophylla* Nees), orchard grass (*Dactylis glomerata* L.), Canada thistle (*Cirsium arvense* Scop.), wild sunflower (*Helianthus* sp.), viper's bugloss (*Echium vulgare* L.), ragweed (*Ambrosia artemisiaefolia* L.), mullein (*Verbascum thapsus* L.), goldenrod (*Solidago* sp.), old witch grass (*Panicum capillare* L.), yarrow (*Achillea millefolium* L.), burdock (*Arctium minus* Bernh.), and tumbling pigweed (*Amaranthus graecizans* L.).

CHARACTER OF INJURY

The European corn borer, as the name implies, is essentially a boring insect, and causes its most important injury by the tunneling and feeding of the larvae within the stems and fruits of the plants attacked. This injury, when severe, results in the collapse or deterioration of the parts of the plant affected, and when less severe the normal functioning of the injured parts may be interfered with if such injury occurs at a critical point. The larvae also feed to a slight extent upon the surface of plants, but such injury usually does not appear measurably to interfere with the normal growth of the host. The specific character of the injury varies somewhat with different groups of hosts and will, therefore, be discussed separately.

CORN

The character of the injury to corn depends upon the stage of growth of the plant when attacked, and also upon the habits and preference of individual larvae. In general, however, the most important and serious injury is caused by the tunneling and feeding of the larvae within the stalks, ear stems, and ears. The larvae also tunnel within the tassel, the midrib of the leaf, the brace roots, the stubble, and in fact all parts of the corn plant except the fibrous roots. They also feed to a slight extent upon the surface of the plant, particularly upon the tender leaf blades, tassel buds, husks, and silks of the ears, and between the leaf sheaths and stalks.

INJURY TO THE LEAVES

Attacks upon young corn plants are characterized by numerous small irregularly shaped feeding areas and the presence of very fine particles of frass. Minute punctures perforating the epidermis appear upon the tender leaf blades surrounding the developing tassel. (Fig. 6.) Such injuries are caused by the feeding of the newly hatched larvae, and, while not economically important, this surface feeding affords a possible opportunity for attacking the larvae by insecticidal means. The midrib of the leaf blade sometimes is entered and tunneled, more particularly by the smaller borers, in the same manner and with the same result as will be described later for the stalk.

INJURY TO THE TASSEL

The tassel buds and the immature branches and main stem of the tassel are often entered and fed upon by the young borers (fig. 6) even before the tassel appears above the unfolding leaf blades. Often several adjoining tassel buds are webbed together with particles of frass and silk by the small larvae. In this condition the infested tassel is very conspicuous after it appears above the unfolding leaves. Frequently the injury to the immature tassel stem causes the breaking over of the tip of the tassel even before it begins to expand.

As the tassel expands and the buds begin to open the larvae continue to tunnel within the branches and the main stem. This injury usually causes the tassel, or the infested portion thereof, to collapse and break over. Such broken tassels (fig. 7), with masses of frass at the breaks, are very conspicuous and often afford the most noticeable sign of the presence of the insect. It does not necessarily follow, however, that because none of the tassels are broken over in a suspected field the insect is not present, as plants sometimes are attacked only at points lower down than the tassel or at a late stage in their development when the tassel or its stem does not attract the larvae.

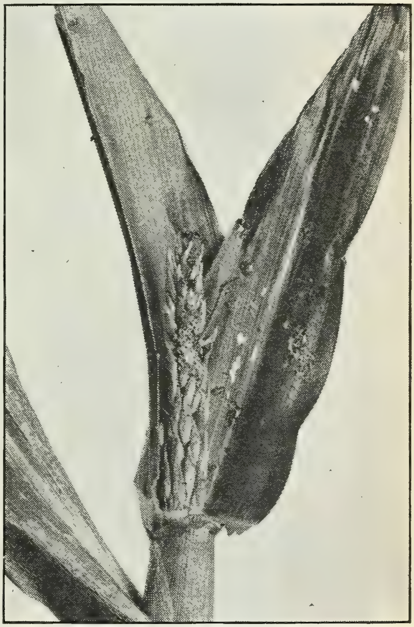

FIG. 6.—Newly developed tassel of corn plant, showing injury by young larvae of the European corn borer. Note small gnawed areas on leaves at right caused by feeding of newly hatched larvae

INJURY TO THE STALK

Some of the newly hatched larvae, instead of tunneling within and feeding upon the tassel buds and tassel stems, habitually migrate to a point lower down on the same or near-by plants. Under these circumstances they commonly enter the plants at practically any point, but the favorite place of entrance is either between the leaf sheath and the stalk (fig. 8) or between the stalk and the base of the partly developed ear (fig. 9), providing the plant has advanced to that stage of growth.

After gaining entrance to the stalk the borer tunnels either upward or downward, usually the former, according to its individual preference. The character of this tunnel is subject to considerable variation, but usually the borer follows nearly a straight course for several inches through the pith and generally lengthwise of the plant. The tunnels of 41 individual borers were found to average 8.6 inches in length. (See Table 14.) The tunnels made by fully grown larvae, when tunneling in green and succulent cornstalks, average 0.19 inch in diameter. In some instances the tunnel is more or less winding, and occasionally small cells are excavated along its course. There is a tendency for the larva to work in the internodes of the stalk, but when necessary it commonly pierces and apparently feeds upon the nodes. All parts of the stalk may be tunneled down to and in-

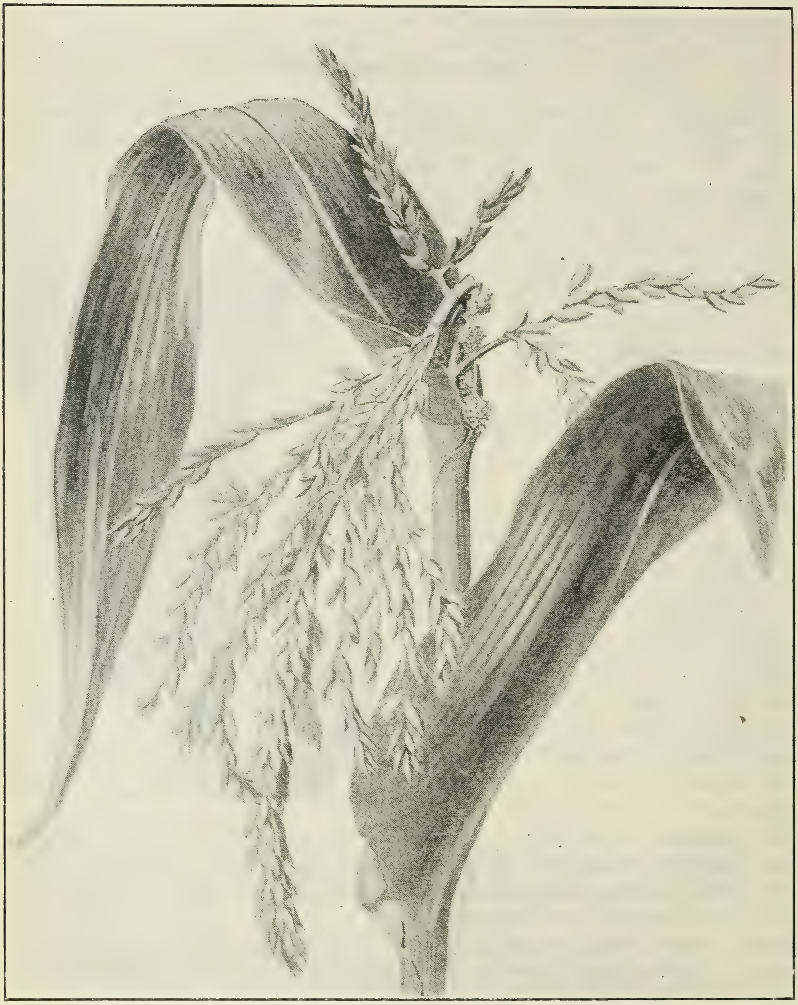

FIG. 7.—Broken corn tassel, showing injury caused by larvae of the European corn borer

cluding the base or stubble. During this tunneling operation large quantities of yellowish-white frass, mixed with silken strands spun by the larva, are pushed out of the entrance hole and suspended there by the silken strands or collected below in the axils of the leaf blades. (Fig. 8.) These masses of frass are very conspicuous and

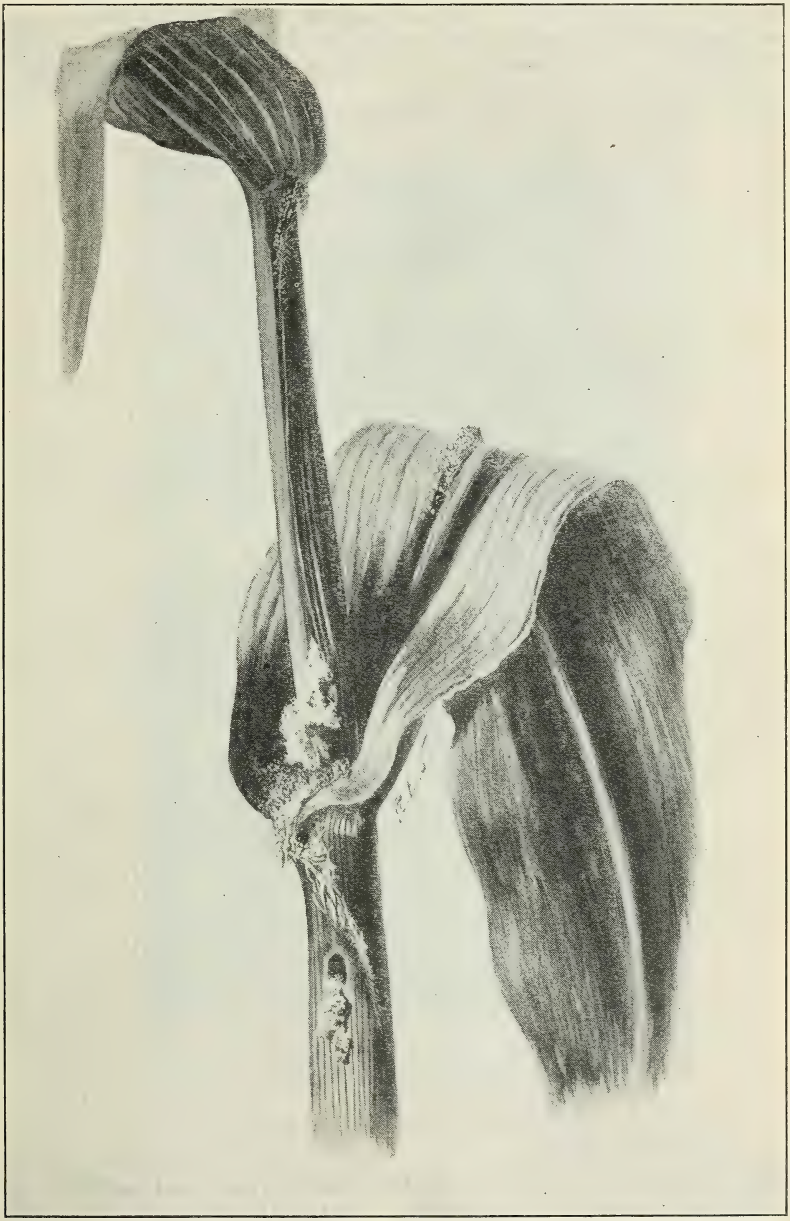

FIG. 8.—Cornstalk, external view, showing extruded frass and entrance to burrow of larva of the European corn borer

serve to attract attention to infested plants at an early stage of the injury. Later in the season, or as the result of heavy rains, much of the frass becomes separated from the plant and falls to the ground.

The tunneling of one or two larvae in a stalk does not always cause appreciable damage; but where, as frequently occurs, several or many borers are tunneling and feeding within the same stalk, it becomes reduced to a mere shell filled with frass and particles of decayed and putrefied plant matter. Naturally the stalk is greatly weakened by this type of injury, and eventually it collapses and breaks over at one or more places. (Fig. 10.) Such breakage may also occur during wind or rain storms as a result of the tunneling of even one or two borers.

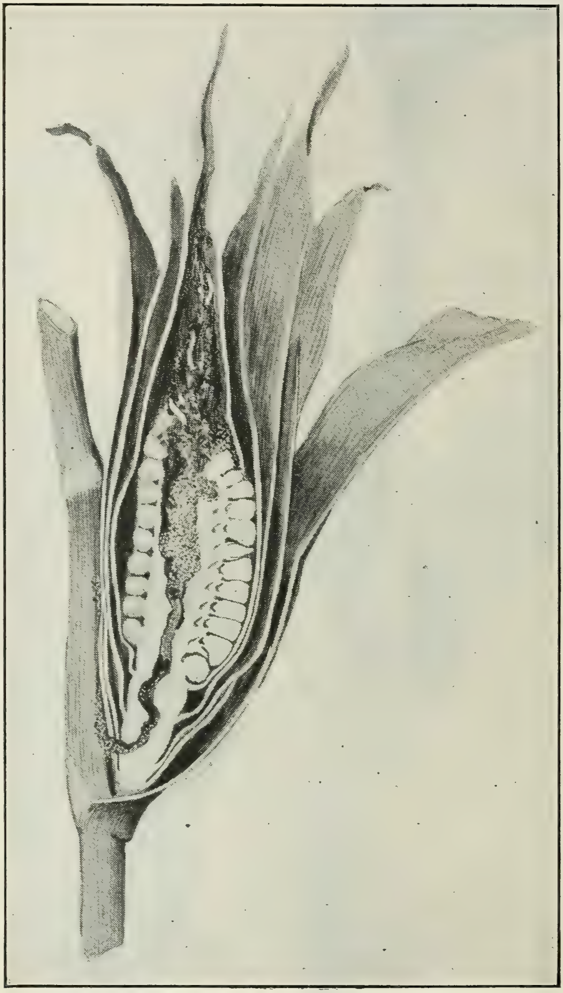

FIG. 9.—Longitudinal section of ear of sweet corn damaged by European corn borer, showing entrance of larva, the stem, and cob

INJURY TO THE EAR

It is evident that the injury to the stalk may indirectly affect the ear by interfering with the supply of nutriment, such injury depending, of course, not only upon the stage of development of the ear during the maximum period of injury, but also upon the degree of injury to the stalk. The ear may be entered directly by the borers (fig. 11) at any stage of their development, at its tip, base, or side; or it may be entered indirectly through the short stem by which the ear is attached to the stalk. Ordinarily the ear is entered at its tip (fig. 9) by small borers which feed first upon the silk, or the tender portion of the husk, subsequently working their way down into the cob and grain. Ears entered in this manner do not always exhibit external evidences of infestation, as the small particles of frass made by the larvae in entering sometimes are very inconspicuous and the external evidences of feeding are small. It frequently is necessary to strip away the husk before evidence of

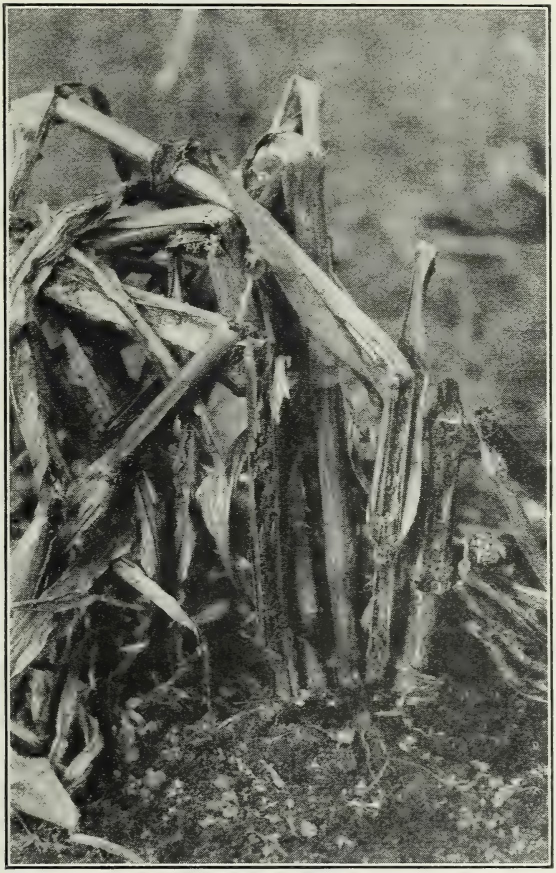

FIG. 10.—"Close-up" of hill of sweet corn ruined by European corn borer. Stalks sectioned to show extensive damage within. There were an average of 37 borers per plant in this field. Medford, Mass., September, 1922

such infestation is disclosed. When once inside the ear, the larvae may tunnel through all parts of the grain and the cob, partially or totally destroying the kernels of grain which they attack. (Fig. 12.) The character of the actual feeding in the grain is subject to wide variation; it may consist of long irregular surface tunnels between the rows of the kernels, or it may consist of tunnels just underneath the upper surface of the kernels, or again large irregular areas may be fed upon with no apparent regularity of procedure. Tunnels in the cob may extend either longitudinally or transversely through it (fig. 13), and when injury of this type occurs early in the development of the ear, it may seriously interfere with the normal formation of the grain. Where several borers are thus feeding upon the grain and the cob, the resulting damage usually is very severe, but when only one or two borers occur within the ear, the damage to the

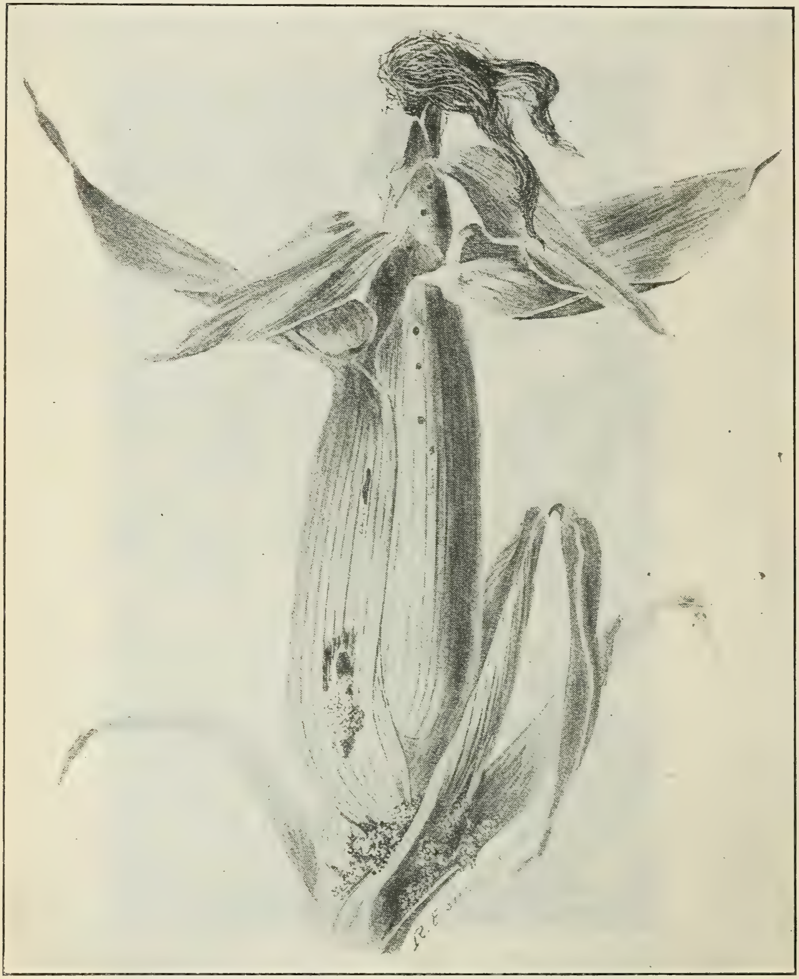

FIG. 11.—External view of ear, showing extruded frass and numerous punctures caused by larvae of the European corn borer

grain may not be appreciable, particularly where this is confined to the tip of the ear or to the interior of the cob.

When the ear is entered from the side or the base the character of the damage is similar to that detailed in the preceding paragraph.

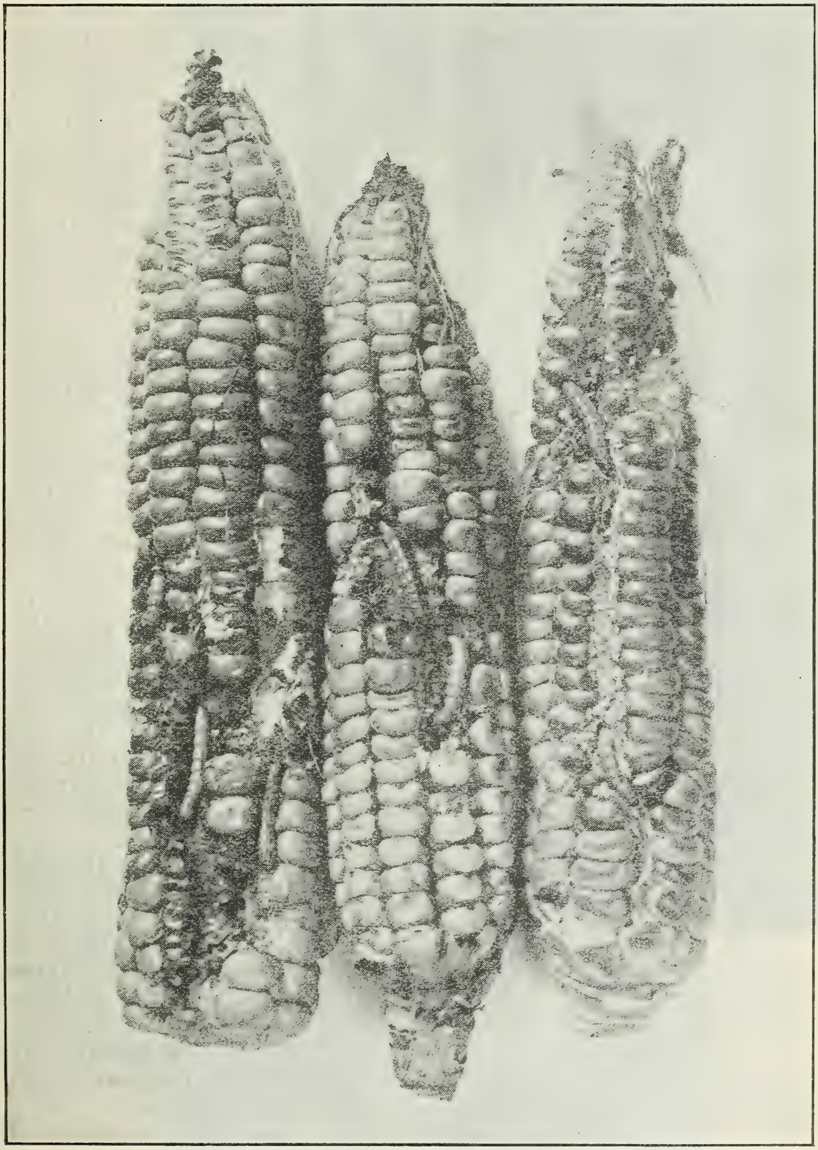

FIG. 12.—Typical injury by the European corn borer to the grain on the immature ears of flint (field) corn. Borers are shown feeding in natural position. The interior of the cobs was also badly tunneled by the borers

The external evidence of infestation, however, usually is more conspicuous, as large masses of frass are thrown out of the entrance hole by the borer, and these become attached to the ear (fig. 11) or the lower part of the plant, as has been previously described.

Borers entering the ear by way of the ear stem (fig. 9) usually cause injury similar to that inflicted by the larvae entering the ear directly. The tunneling in the ear stem, when severe, and occurring early in the development of the ear, may interfere with its supply of nutriment. Furthermore, the ear stem is weakened by such injury and frequently breaks over (fig. 14) before the ear has completed its development. In instances where the injury to the ear stem is slight, or when such injury occurs after the ear is nearly mature, no appreciable damage to the grain results, even though the ear breaks over. Many ears thus affected, however, fall to the ground long before harvest and are subject to deterioration by rots and other destructive agencies. When, as sometimes occurs, a large proportion of the ears have fallen to the ground (fig. 15), the expense of harvesting is increased.

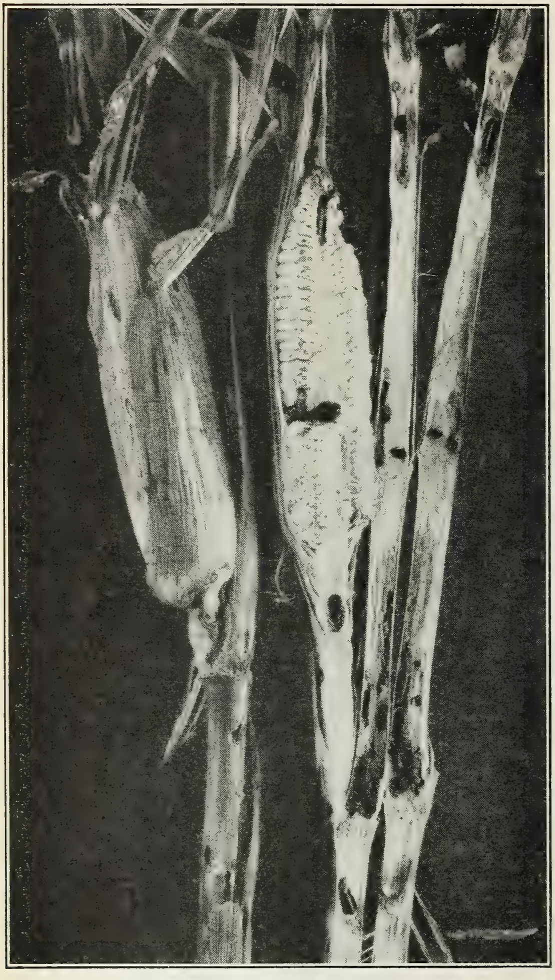

FIG. 13.—Typical injury by the European corn borer to stalks and ears of sweet corn at roasting-ear stage. Pupae of the first generation are shown in position. One hundred per cent of the stalks and 99 per cent of the ears were infested in this field by the first generation. Saugus, Mass., August 1, 1922

Injury to the ears, even where these remain attached to the plant, often is increased by the ingress of rots and molds as a result of the work of the borers, and aids in reducing even slightly infested ears to a soft decaying condition, thus sometimes entirely destroying its food value.

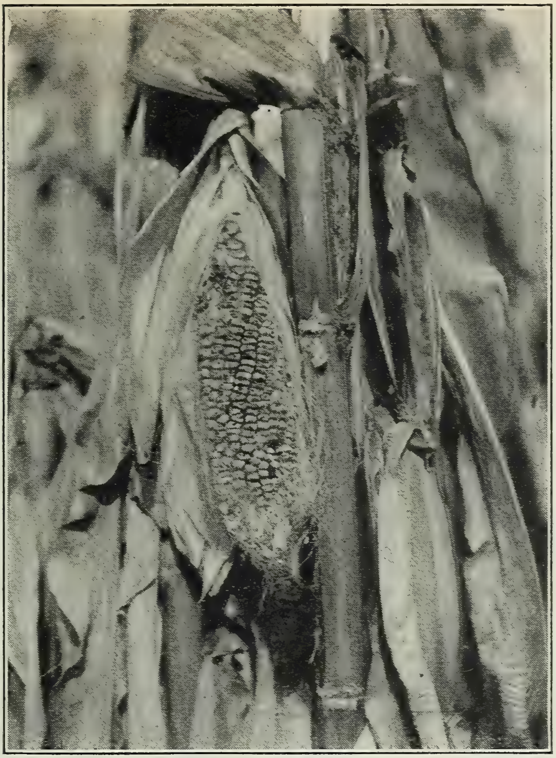

FIG. 14.—"Close-up" of dent field corn ear and stalk, showing typical injury by the European corn borer. This experimental plat showed an average of 2.5 per cent grain injury, 62.2 per cent ears infested, 100 per cent stalks infested, with an average of 15.5 larvae per plant. Cambridge, Mass., October, 1920

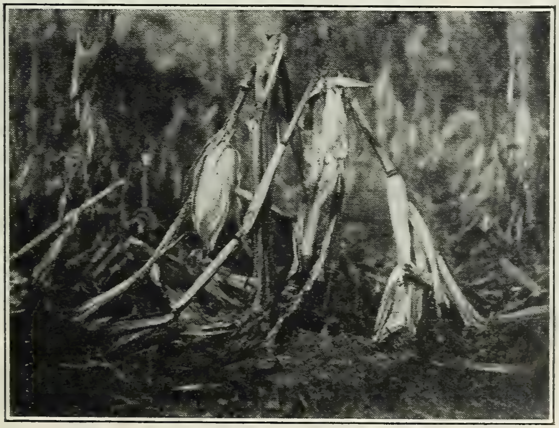

FIG. 15.—Hill of flint field corn, showing severe European corn-borer infestation. Note broken-over stalks and ear lying on the ground. Cambridge, Mass., October, 1920

CHARACTER OF INJURY TO PLANTS OTHER THAN CORN

Injury to plants other than corn is of the same general character as that inflicted on corn, except that in some instances special parts of the plants appear to be habitually preferred as food or as shelter. (See Table 1.)

Although some of the infestation in plants other than corn results from the larvae which have migrated from susceptible plants growing in the vicinity, such as corn or weeds, the eggs are commonly deposited upon a variety of vegetables, field crops, flowering plants, and weeds. Many of the resulting larvae feed and complete their development therein, particularly in the two-generation area of New England.

VEGETABLES

In addition to sweet corn, the most important vegetable hosts of *P. nubilalsis* (Table 2) are rhubarb, beets, mangels (fig. 16), celery, beans, spinach, peppers, tomatoes, potatoes (fig. 17), and Swiss chard. A summary of the more important observations relating to the character of injury to these plants is included in Table 2. With the exception of beans, which were slightly infested in the experimental plat at Silver Creek, N. Y., all of these observations are limited to the New England area.

TABLE 2.—*Character of injury to vegetables by Pyrausta nubilalis larvae*
(New England, 1918 to 1922)

Name of plant	Parts of plant attacked	Appearance of infested plants	Remarks
Rhubarb	Leaf stalks, seed stalks, and main veins of leaves. Eggs deposited freely on leaves. Small larvae feed thereon.	Masses of dark-yellow frass, mixed with gumlike substance, exude from larval tunnels. Affected parts break over when injury is severe.	Most susceptible of vegetable crops. Much of the severe injury occurs after close of commercial season. Plant not seriously affected by this injury.
Beets	Leaf stalks, main veins of leaves. Rarely the fleshy portion of root. Eggs deposited freely on leaves. Small larvae feed thereon.	Black, granular frass ejected from larval tunnels. Affected parts break over when injury is severe.	Plants very susceptible. Injury to leaves or leaf stalks does not seriously affect plant. Injury to beet root renders it unsuitable for food.
Celery	Leaf stalks, main veins of leaves. Usually outer leaf stalks preferred, although frequent injury to heart of plant. Eggs deposited on leaves.	Wet, discolored frass ejected from larval tunnels. Unless badly infested the injured leaf stalk does not break over.	Plants very susceptible. Injury to leaf stalk renders it unfit for food. Usually the injured portion may be removed and remainder of plant used.
Beans	Principally stalks, occasionally green beans and pods. Eggs deposited on leaves.	Masses of light-yellow frass extrude from larval tunnels. Affected parts break over when injury is severe.	Both low bush and pole beans attacked. Usually the severe injury occurs after beans have reached harvesting stage. Number of infested pods usually less than 1 per cent of total in field.
Spinach	Leaves fed upon by newly hatched larvae. Leaf stalks rarely tunneled. Eggs deposited on leaves.	Light-yellow frass ejected from larval tunnels. Injury very inconspicuous.	Infestation by eggs or larvae usually limited to less than 1 per cent of plants in field. Growth of plant not affected.
Pepper	Stalks and fruit	Light-yellow frass ejected from larval tunnels. Infested stalks break over. Seeds and pulp of fruit eaten.	Both sweet and hot varieties are attacked. Formation of fruit affected when stalks are attacked early. External signs of infested fruit not conspicuous.
Tomato	Stalks, and rarely the fruit.	do	Do.
Potato	Stalks. Eggs freely deposited on leaves. Small larvae feed thereon.	Same as above. Tubers not infested.	Even severe breaking over of stalks does not appreciably affect formation of tubers.
Swiss chard	Leaf stalks. Eggs occasionally deposited on leaves. Small larvae feed thereon.	Black masses of frass ejected from larval tunnels. Usually the tunnel is discernible from surface of leaf stalk.	Growth of plant not appreciably affected. Injured parts unsuitable for food. Usually the affected parts do not break over.

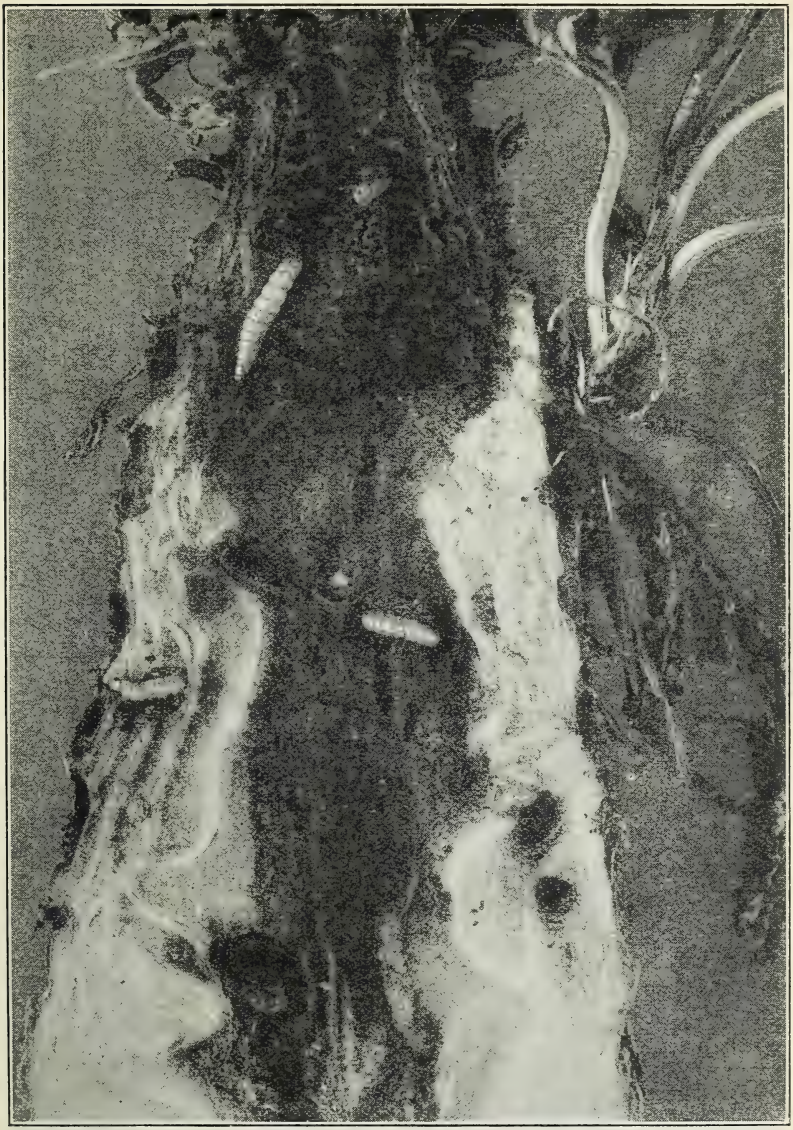

FIG. 16.—Mangel severely injured by European corn borer. Note extensive decay following work of borers. As many as 60 borers were found in a single mangel. Winchester, Mass., November 1, 1922

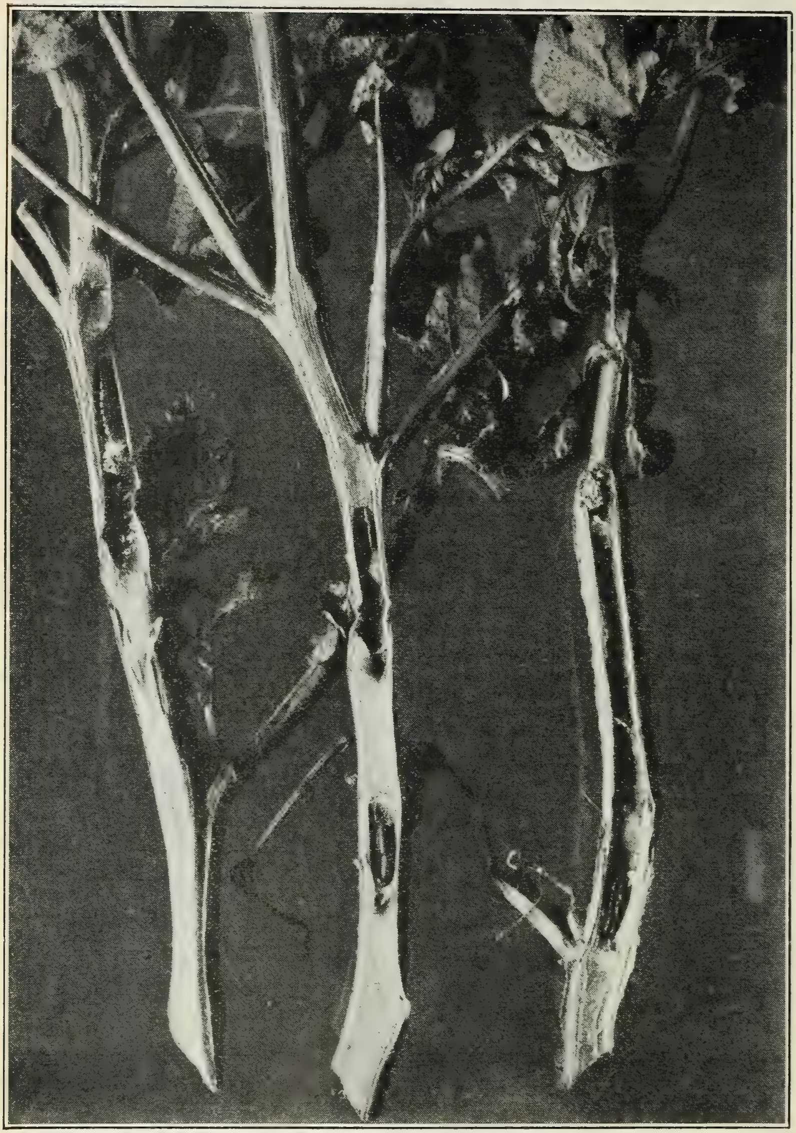

FIG. 17.—Potato stalks sectioned to show typical work of European corn borer larvae therein and pupae in position. Fifty-four per cent of the plants in this field were infested. Winchester, Mass., July 27, 1922

FIELD CROPS

Practically none of the common field crops, with the exception of timothy and oats (fig. 18), are grown to any extent within the area where *P. nubilalis* has become well established in New England. It was necessary, therefore, to grow small experimental plats of the more important field crops at Medford, Saugus, Cambridge, Belmont, and Woburn, Mass., in order to ascertain the reaction of the insect to them. It seemed desirable to include such other important field crops as are normally grown in the South and West, with the object of obtaining advance information regarding the adaptability of the insect to these crops.

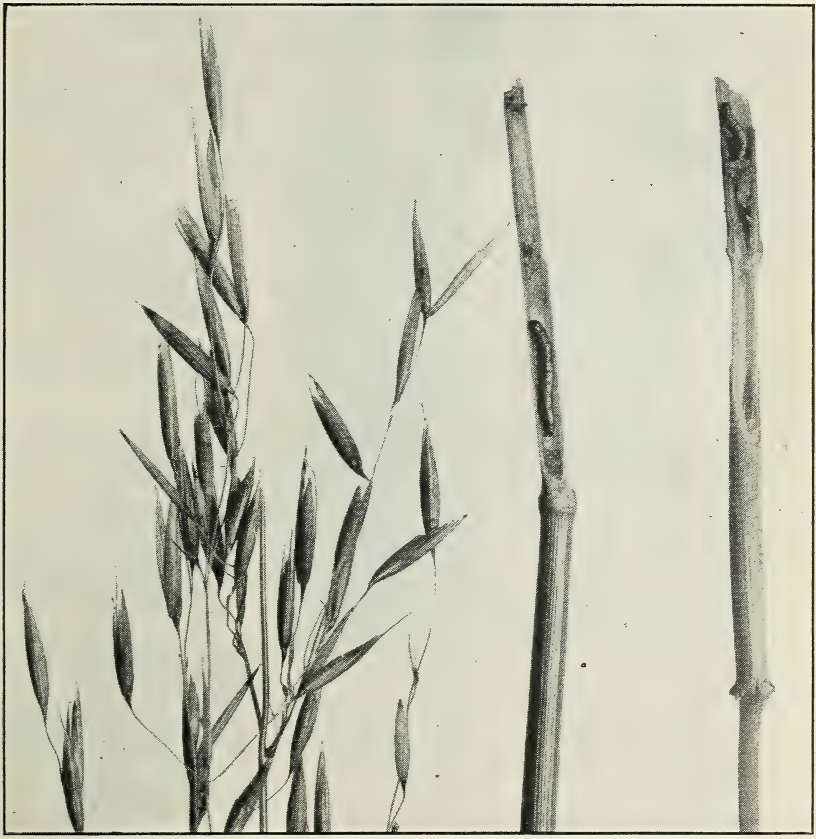

FIG. 18.—Oats showing European corn-borer larvae infesting stem

The experimental plats were duplicated at Scotia and Silver Creek, N. Y., but most of the information included herewith was obtained from the Massachusetts plats, where the insect is more numerous and habitually attacks a greater variety of plants under field conditions. The results obtained should be considered as merely indicative, because it does not seem possible definitely to forecast the reaction of *P. nubilalis* to some of these crops, under American conditions, if the insect should become well established where they are extensively grown. A summary of the observations relating to the character of injury to field crops is included in Table 3.

TABLE 3.—*Character of injury to field crops by Pyrausta nubilalis larvae*

(New England, 1919 to 1922)

Name of plant	Parts of plant attacked	Appearance of infested plants	Remarks
Millet	Stems (culms). Eggs rarely deposited on leaves.	Masses of light-yellow frass extrude from larval tunnels. Infested stems usually break over.	Japanese millet very susceptible. European millet to a lesser extent. Hungarian millet rarely attacked.
Hemp	Stalks, seed heads. Eggs freely deposited on leaves. Small larvae feed thereon.	Same as above. Plants break over only when severely injured.	Very susceptible. Found occasionally growing wild in Massachusetts area. Invariably infested when exposed to attack.
Grain sorghums.	do	Red frass ejected from larval tunnels. Stalk breaks over just below seed head when severely injured. Resembles injury to tassel stem of corn.	Includes hegari, feterita, milo, and kafir. Hegari most susceptible and more severely injured than the others of this group.
Broomcorn	do	do	Appears to be able to withstand severe infestation without appreciable injury to the brush used in broom making.
Barley	Stems (culms)	Masses of light-yellow frass ejected from larval tunnels. Infested stems usually break over.	Formation of grain seriously affected when stem is attacked early in its development. Late attack not seriously injurious.
Cotton	Stalks, bolls. Eggs freely deposited on leaves. Small larvae feed thereon.	Same as above. Bolls entered at base, under bracts, when nearly full grown. Dark-brown frass extrudes from entrance holes. Larvae tunnel through carpel, lint, and seed.	Quite susceptible. Development of bolls prevented when stalk breaks over early in its development. Bolls not affected by slight or late injury to stalk. Plants killed by frost before bolls opened.
Cowpea	Stalks, pods. Eggs occasionally deposited on leaves.	Masses of light-yellow frass extrude from larval tunnels. Infested stems usually break over. Injury to pods similar to beans.	Most of injury occurs late in the season. Growth of plant or yield of seed not appreciably affected.
Sorgo	Stalks, seed heads. Eggs freely deposited on leaves. Small larvae feed on leaves.	Appearance of injury similar to corn. Plants break over only when severely injured. Frass red in color.	Except when severely injured the growth of plants infested is not seriously affected.
Hop	Vine (stem) and leaf stems.	Light-yellow frass ejected from larval tunnels.	Only occasionally infested.[1]
Buckwheat	Stems	Masses of white frass extrude from larval tunnels. Infested stems usually break over.	Grains reduced in size or their formation prevented entirely when injury occurs before seed head develops.
Oats	Stems (culms). Eggs rarely deposited on leaves.	do	Do.
Johnson grass	do	do	Yield of fodder or seed not appreciably affected.
Sudan grass	do	do	Do.
Soy bean	Stalks. Feeding injury to leaves. Eggs found on leaves.	Masses of light-yellow frass extrude from larval tunnels. Plants break over when severely injured.	Plants infested late in the season. Growth of infested plants not appreciably affected. Soy beans infested under field conditions in New York.
Rape	Leaf stalks	do	Very slightly susceptible. No appreciable effect on plant.
Sweet clover (white).	Stems	do	Same as above. White sweet clover grows wild in waste areas, in vicinity of Boston, Mass.
Timothy	Stems, seed heads	do	Infested usually by smaller larvae. Full-grown larvae found rarely in larger stems.
Tobacco	Stalks	Masses of dark brown frass extrude from larval tunnels.	Infestation occurs during late season. No appreciable effect on plant. Larvae found in tobacco were dead, or died subsequently.

---

[1] Japanese hop (*Humulus japonicus*) is grown as an ornamental in Massachusetts and under these conditions it is frequently and severely infested.

FLOWERING PLANTS

Although a large number of flowering plants are known to be attacked by *P. nubilalis* (Table 1), the most important of this group, considering their susceptibility and economic importance, are dahlia, China aster, chrysanthemum, zinnia, calendula, canna, cosmos, geranium, gladiolus (fig. 19), golden glow, hollyhock, and salvia. A summary of the more important observations relating to these plants is included in Table 4. With the exception of cosmos and dahlia, which were slightly infested in the experimental plat at Silver Creek, N. Y., all of these observations are limited to the New England area.

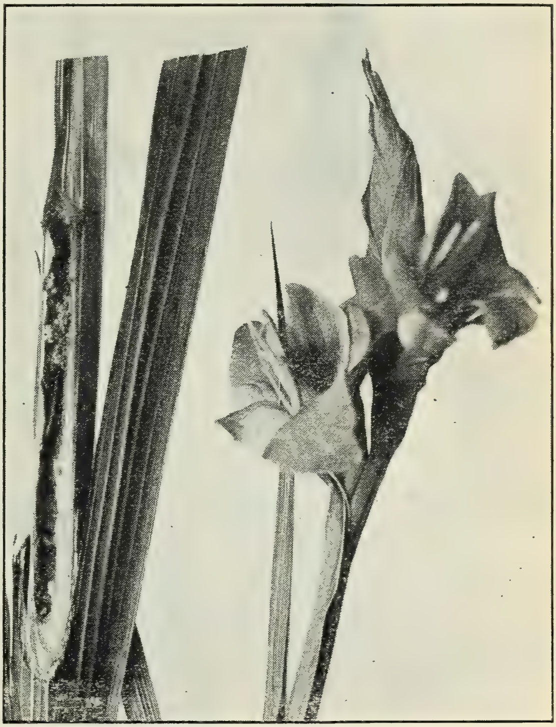

FIG. 19.—Gladiolus stem, showing European corn-borer infestation

WEEDS

The character of the injury to the weeds and wild grasses which are attacked by the European corn borer (Table 1) is essentially the same as has been described for corn and other economic hosts of the insect. Eggs are deposited upon some of these weeds and wild grasses, particularly in the New England area, and the resulting larvae may complete their development and pupate within, or may migrate to various other host plants in the vicinity. In addition, these plants frequently are infested by larvae migrating from near-by crops, notably corn. The injury to weeds and wild grasses is characterized by the collapse and breaking over of the stems or stalks which are severely infested. In weed infestation, such as occurs in barnyard grass, the larvae tunnel through the stalks and stems, even including the base of the stalk, or stubble, to a point below the surface of the ground. (Fig. 20.) The percentages of infestation in some of the more susceptible weed hosts are shown in Table 20.

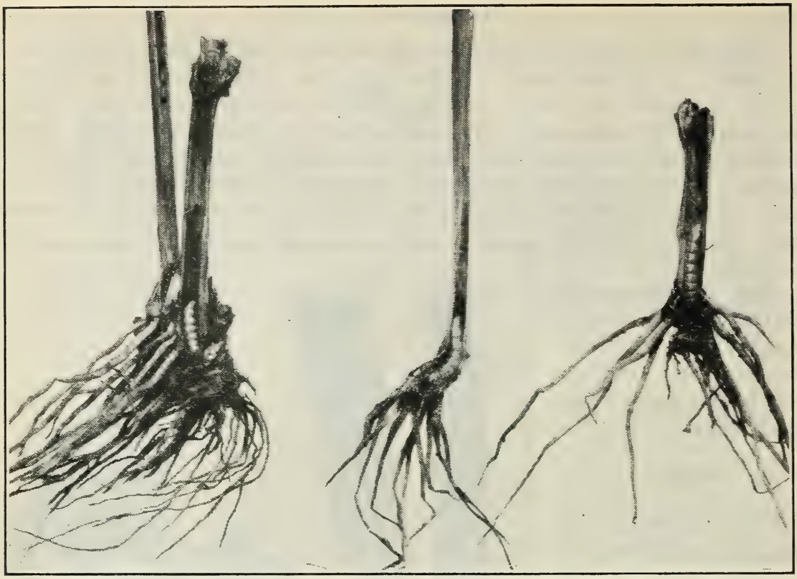

FIG. 20.—European corn-borer larvae at base of barnyard-grass stubble

TABLE 4.—*Character of injury to flowering plants by Pyrausta nubilalis larvae*

(New England, 1918 to 1922)

Name of plant	Parts of plant attacked	Appearance of infested plants	Remarks
Dahlia	Stalks, flower stems, and flowers. Eggs freely deposited on leaves. Small larvae feed thereon.	Large masses of light-yellow frass extrude from larval tunnels. Affected plants wilt and and break over when severely injured.	Most susceptible of the flowering plants. Injury most severe at time of blooming. Entire planting frequently infested. Roots (tubers) not infested.
China aster	Stalks and flowers. Eggs rarely deposited on leaves.	Same as above. Most of injury to middle part of stalk. Affected stalks usually break over.	Frequently infested in field and in greenhouse. Production of blooms usually reduced or prevented entirely.
Chrysanthemum.	Stalks, flower stems, and flowers. Feeding areas on leaves but no eggs found.	do	Greenhouse and hardy varieties very susceptible. Size of blooms not affected by slight or late injury to stalks. Blooms reduced in size or prevented entirely by early breaking over of the stalk.
Zinnia	Stalks, flower stems, and flowers. Eggs rarely deposited on leaves.	do	Same as above except not found infested in greenhouse. Rarely grown under glass.
Calendula	Stalks, flowers	do	Same as above. Rarely found infested in greenhouse.
Canna	Stalks, midrib of leaves and flowers. Feeding areas on leaves but no eggs found.	Light-brown frass extrudes from larval tunnels. Most of injury to midrib of leaf.	Seldom infested except when growing near other infested plants. No infestation found in roots.
Cosmos	Stalks. Rarely in flower stems.	Large masses of light-yellow frass extrude from larval tunnels. Affected parts break over when severely injured.	Most of injury to main stalks, late in season. Flower buds seldom open on part of plant broken over. Not found infested in greenhouse.
Salvia	Stalks, flower stems	do	Do.
Geranium	Stalks	do	Do.
Hollyhock	Stalks, leaf stems	do	Same as above. Leaf stems of young plants particularly susceptible.
Gladiolus	Stalks and flowers. Eggs occasionally deposited on leaves. Small larvae feed thereon.	do	Weakened or broken stems often render the spike unmarketable. Slight injury to flower stems, no appreciable effect on spike. Not infested in greenhouse.
Golden glow	Stalks, flower stems. Eggs rarely deposited on leaves.	do	Most of injury occurs late in season after flowers have formed. No appreciable injury to plant.

EXTENT OF INJURY AND ECONOMIC LOSS

CORN

Most of the direct injury and loss to corn, as a result of European corn-borer attack, is caused by the larvae feeding on the grain and in the cob of the ear. (Fig. 21.) In addition to this direct loss to the ear there is also an indeterminate amount of indirect loss, as previously described. The injury to the lower stalks and ear stem, if severe and occurring before the ear is nearly mature, frequently results in a small or poorly formed ear. The actual extent of injury and economic loss resulting from the indirect injury to the ear and the stalk is difficult to estimate definitely, as it varies greatly in different fields and depends upon several factors, the most important of which are (1) percentage of plants infested, (2) the number of borers per plant, (3) the stage of development of the plant when attacked, (4) the part of the plant selected for attack, and (5) the

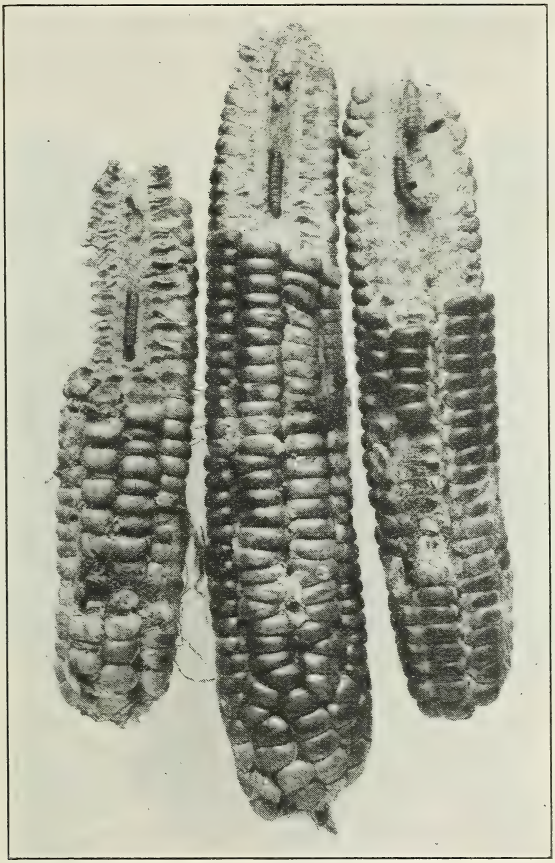

FIG. 21.—European corn-borer injury to grain and cob of flint field corn. Cobs sectioned to show borers within. One hundred per cent of the stalks and ears were infested and 17 per cent of the grain destroyed in the field from which these ears originated. Medford, Mass., October, 1922

habit of growth (size of stalk) of the variety. In general, however, it may be conservatively estimated that in most of the infested fields the indirect loss at least equals and frequently exceeds the direct loss sustained by the feeding of the borers on the grain. The exit and entrance holes of the larvae in the ears and stalks also provide a means for the entrance of various rots and molds, as previously stated.

The percentage of plants injured and the economic loss incurred have been greater as a rule in New England than in the other areas in the United States where the insect is present.

EXTENT OF INJURY AND LOSS TO EARS, GRAIN, AND STALKS

New England

In order to obtain data relative to the direct injury and loss to ears, grain, and stalks in the New England area, a series of detailed examinations were made during 1920 in the plats of flint, dent, and sweet corn grown in the experimental fields at Medford, Saugus, and Cambridge, Mass. These examinations were repeated during 1921 and 1922 in plats grown at Medford and at Arlington. Each of these plats was approximately one-twentieth of an acre in size and consisted of 8 varieties of flint corn, 12 varieties of dent corn, and 13 varieties of sweet corn. Most of the varieties of flint and sweet corn used in these experiments are those commonly grown in New England, but the dent varieties are very seldom grown in the Boston area for grain. However, owing to the importance and widespread use of dent corn in many sections of the country, it was desired to ascertain the susceptibility of this type to attack by *Pyrausta nubilalis*, although only the earlier dent varieties will mature in the Boston area, even under favorable seasonal conditions.

Table 5.—*Extent of injury and loss caused by the European corn borer to ears, grain, and stalks of field and sweet corn in experimental plats of the New England area, 1920 to 1922*

Locality (Massachusetts)	Number of plats			Ear examination						Per cent of grain injured or destroyed on ears examined			Stalk examination					
				Number examined			Per cent infested						Number examined			Per cent infested		
	1920	1921	1922	1920	1921	1922	1920	1921	1922	1920	1921	1922	1920	1921	1922	1920	1921	1922
Flint corn:																		
Medford	7	3	1	350	150	50	94.2	81.3	100	8.5	3.0	17.0	700	300	100	97.0	98.7	100
Saugus	4	----	----	200	----	----	75.2	----	----	10.0	----	----	400	----	----	99.0	----	----
Cambridge	3	----	----	150	----	----	85.3	----	----	18.3	----	----	300	----	----	100.0	----	----
Dent corn:																		
Medford	11	3	1	550	150	50	84.2	66.7	100	2.5	.6	28.7	1,100	300	100	93.6	96.0	100
Saugus	4	----	----	200	----	----	63.0	----	----	1.2	----	----	400	----	----	95.6	----	----
Cambridge	5	----	----	250	----	----	62.3	----	----	2.5	----	----	500	----	----	100.0	----	----
Arlington	----	----	1	----	----	50	----	----	100	----	----	11.7	----	----	100	----	----	100
Sweet corn: [1]																		
Medford	20	12	13	2,000	1,200	1,300	55.5	45.7	74	1.2	.4	2.9	2,000	1,200	1,300	34.2	(2)	(2)
Saugus	10	----	----	1,000	----	----	52.0	----	----	.8	----	----	1,000	----	----	33.5	----	----

	Flint	Dent	Sweet
Three-year average (per cent):			
Ear infestation	86.7	74.6	57.1
Grain injury	10.0	3.14	1.4
Stalk infestation	98.4	96.0	[2] 33.9

[1] At roasting-ear stage of growth.

[2] Complete counts not taken in 1921 and 1922.

The experimental fields were located where the corn borer has become well established, and the infestation and injury to the corn in these fields represented ordinary conditions. Moreover, the fact that these varieties were grown in adjacent plats under the same cultural conditions provides an indicative basis for comparison of relative susceptibility of varieties and types. The fields wherein these plats were located received a thorough clean-up and plowing during the preceding fall, or in the spring, so that the conditions of infestation prior to planting were much better than those existing in commercial fields of the vicinity. Most of the subsequent infestation in these plats, particularly that by the first generation, is believed to have been caused by the flight of moths from adjoining fields. The results of the examinations of the experimental plats are shown in Table 5.

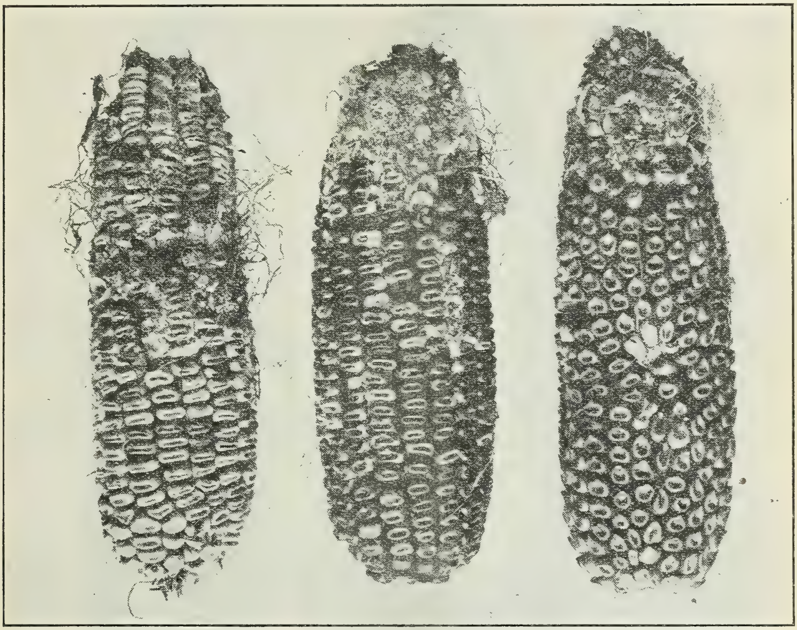

FIG. 22.—European corn-borer injury to grain of dent field corn. The cobs and ear stems were also badly tunneled by the borers. The experimental plat from which these ears originated showed 28.7 per cent grain injury, with 100 per cent of ears and stalks infested. Medford, Mass., October, 1922

The counts shown in Table 5 were made at the time of harvest; 50 ears were selected at random from each plat of field corn when mature and 100 ears selected in the same manner from each plat of sweet corn at the roasting-ear stage. The stalk infestation was based upon an examination of 100 stalks from each plat. The actual grain injury to sweet corn is not indicative of the real loss, as many ears which suffered only slight damage to the grain at the roasting-ear stage were rendered unfit for market purposes or for canning. The grain injury to dent corn in comparison with flint corn is somewhat affected by the fact that in the 1920 series 4 of the varieties of dent corn did not mature under Boston conditions. According to experimental evidence obtained in Massachusetts during 1922 (Table 5), under conditions of severe infestation, the ears (fig. 22) and stalks of the early-maturing or short-season varieties of dent corn are as susceptible to severe injury by *P. nubilalis* as the ordinary sweet or flint corn varieties. In general, however, the infestation and injury to dent corn, particularly the large-stalked and late-maturing varieties, has been less severe than to the earlier maturing and smaller-stalked varieties of flint corn. It is a matter of speculation whether this relative susceptibility and injury would be retained in regions where the duration of the growing season permitted the maturity of large dent corn varieties. Flint and sweet

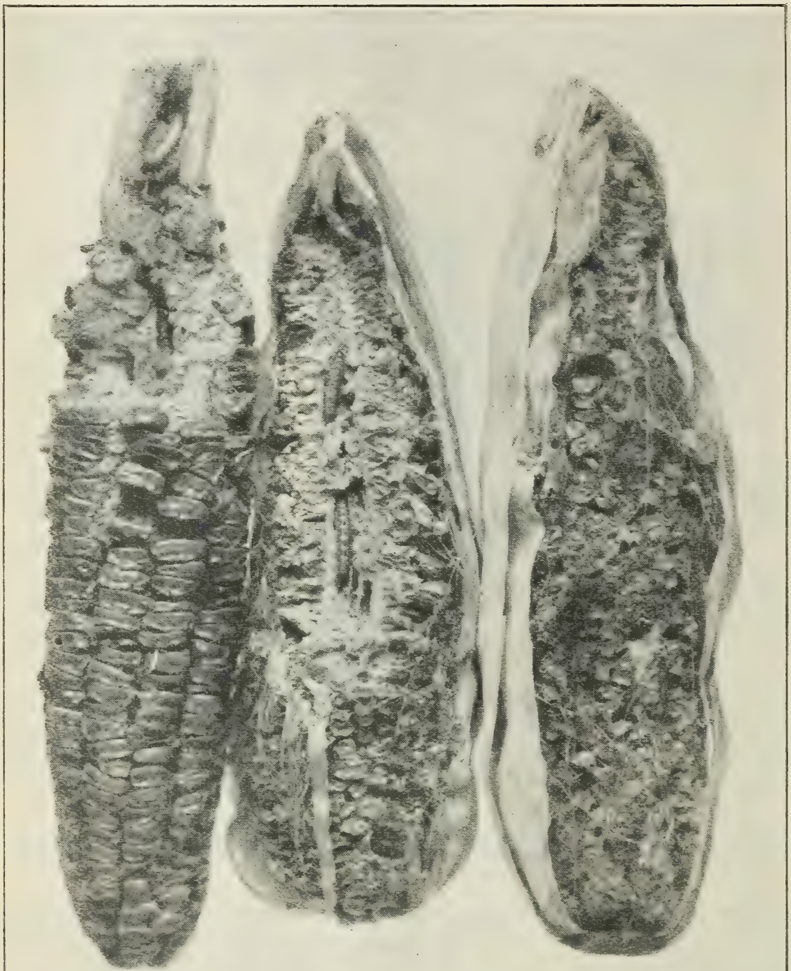

FIG. 23.—Ears of sweet corn left to ripen for seed, showing severe injury to grain and cob by European corn borer. Two cobs cut open to show borers within. Also note severe injury to ear stem. Medford, Mass., September, 1922

corn appear to be about equally susceptible to infestation and injury, although the commercial injury to the ears and grain of sweet corn is limited to the development of the ear to the roasting-ear stage, unless grown for seed (fig. 23), and therefore does not serve as a real comparison of susceptibility with flint corn grown for grain.

Table 6 gives data relative to the injury and loss to ears, grain, and stalks of flint field corn and sweet corn during the period 1920 to 1922 in representative commercial fields in that portion of the New England area where the insect has become well established. All of the flint cornfields grown within this area are included. Since dent field corn is seldom grown commercially for grain in that part of the New England area now infested by the corn borer, there were no fields of this type available for examination. The sweet corn fields included herein were selected on the basis of personal judgment of average conditions and not by the use of arithmetical methods. The injury and loss in certain small fields of sweet corn representing the maximum infestation (fig. 24) was greater than these figures indicate. No complete information is at hand relative to the clean-up measures employed in all of these fields during the preceding fall and spring, but judging from the usual practice in the section where these fields were located it is probable that all standing cornstalks were removed in the fall, and that the corn stubble, other crop refuse, and weeds were plowed under, either in the fall or spring. This type of field practice, however, usually results in leaving undisturbed large numbers of infested weeds along the field borders.

TABLE 6.—*Extent of injury and loss caused by the European corn borer to ears, grain, and stalks of field and sweet corn in the New England area, 1920 to 1922*

Locality (Massachusetts)	Acreage of fields examined			Ear examination						Per cent of grain injured or destroyed on ears examined			Stalk examination					
				Number examined			Per cent infested						Number examined			Per cent infested		
	1920	1921	1922	1920	1921	1922	1920	1921	1922	1920	1921	1922	1920	1921	1922	1920	1921	1922
Flint corn:																		
Medford	2.0	----	----	50	----	----	96.0	----	-----	4.0	----	-----	200	----	----	98.0	----	-----
Wakefield	4.0	7.0	2.0	50	50	100	24.0	70	39.0	.3	1.5	1.9	850	700	200	40.9	60	100.0
Arlington	1.5	1.0	----	50	100	----	80.0	96	-----	10.4	7.3	-----	300	200	----	100.0	100	-----
Stoneham	3.5	4.0	----	50	50	----	58.0	66	-----	3.8	2.2	-----	750	800	----	94.0	78	-----
Scituate	----	----	1.5	----	----	100	----	----	100.0	----	----	10.0	----	----	300	-----	----	100.0
Sweet corn: [1]																		
Arlington	2.5	----	----	100	----	----	64.0	----	-----	3.1	----	-----	500	----	----	88.0	----	-----
Watertown	3.5	4.5	----	100	100	----	44.0	72	-----	4.1	2.8	-----	200	300	----	100.0	89	-----
Medford	----	6.0	5.0	----	100	100	----	46	37.0	----	.5	.2	----	500	100	-----	98	100.0
Melrose	----	----	6.0	----	----	300	----	----	57.6	----	----	.3	----	----	300	-----	----	72.7
Saugus	----	----	5.0	----	----	200	----	----	82.5	----	----	3.9	----	----	300	-----	----	100.0
Winchester	----	----	4.25	----	----	400	----	----	42.5	----	----	.4	----	----	300	-----	----	63.0
Woburn	----	----	7.5	----	----	500	----	----	10.0	----	----	.02	----	----	500	-----	----	24.0

	Flint	Sweet
Three-year average (per cent):		
Ear infestation	71.9	43.2
Grain injury	5.1	1.1
Stalk infestation	76.6	77.5

---

[1] At roasting-ear stage of growth.

The figures in Table 6 show an important amount of direct loss from ear infestation and grain injury to both flint and sweet corn. The susceptibility to infestation of flint field corn and sweet corn was nearly equal in these fields as shown by the average percentages of stalk infestation of 76.6 and 77.5 for the flint and sweet types, respectively. The difference between the percentages of ear infestation and grain injury of the two types is due to the fact that the sweet-corn ears are harvested before maturity, and therefore are exposed to injury for a shorter period than the flint corn.

During 1922 a series of examinations were made throughout the season in 50 fields of sweet corn, aggregating 63.5 acres, taken at random in 20 towns of the New England area. These examinations were made at harvest (roasting-ear stage) and on a basis of 100 ears and 100 stalks to each field. In 9 of these fields none of the ears were infested. In the remaining 41 fields the percentage of ears infested ranged from 1 to 100, the average for the entire 50 fields (5,000 ears) being 20.4 per cent. The stalk infestation for the 50 fields averaged 56.5 per cent. The majority of the ears found to be infested were unfit for market. A similar examination conducted in 66 fields of the New England area during 1923 gave an average ear infestation of 10.6 per cent, and during 1924 an average of only 1.2 per cent of the sweet-corn ears were found infested in 52 fields of the same area.

As a part of the investigation to determine the progress of annual increase or decrease of infestation, careful counts were made in 1921 and 1922 in the cornfields of 40 townships of New England, representing all conditions of infestation from the center of the area to the lightly infested townships near the border of the area. In these field counts 10 fields (or garden patches in residential districts) were selected in each town, such selections being made on the basis of the personal judgment of the field worker as to what constituted fields which were representative of the entire town. In figuring the averages the results from all fields, whether infested or noninfested, were included.

The majority of these fields were, of necessity, sweet corn. These counts show that in 1921 an average of 29.93 per cent of the stalks were infested in these 40 towns, including noninfested as well as infested fields, with an average of 4.44 larvae per infested stalk (132.9 larvae per 100 stalks); while in 1922 an average of 53.29 per cent of the stalks were infested in these same towns, with an average of 8.75 larvae per infested stalk (466.3 larvae per 100 stalks). These figures are believed to represent accurately the average conditions throughout the New England area for this two-year period. Comparable figures for the 1923 field survey show that in the 222 fields examined in 22 of the same towns included in the 1921 and 1922 surveys there were an average of 30.1 per cent of the stalks infested, containing an average of 3.8 larvae per infested stalk (114.5 larvae per 100 stalks); while in 1924 there were an average of 18.2 per cent of the stalks infested in the 178 fields examined in 35 of the same towns included in the 1923 survey, containing an average of 2.2 larvae per infested stalk (40 larvae per 100 infested stalks).

The annual surveys have shown a very significant decrease in the acreage planted to corn each year, especially in that portion of the territory where the insect has become numerous. The decrease in aggregate acreage in 1922, as compared to 1921, was approximately 50 per cent in the 40 towns.

NEW YORK

The extent of injury and economic loss caused by the corn borer in New York State has been comparatively slight to date. Except in a very few fields the infestation has not approached that existing in New England.

EASTERN NEW YORK

Table 7 gives data relative to the injury and loss to ears, grain, and stalks of flint, dent, and sweet corn, during the period from 1920 to 1922, in that portion of the eastern New York area where the corn borer is known to have been present for at least four years and where it has become fairly well established, although it is probably not now as numerous in this area as may be expected in the future. Some of the smaller fields representing the maximum infestation in this area are not included in the table.

TABLE 7.—*Extent of injury and loss caused by the European corn borer to ears, grain, and stalks of field and sweet corn in eastern New York, 1920 to 1922*

Locality (eastern New York)	Acreage of fields examined			Ear examination						Per cent of grain injured or destroyed on ears examined			Stalk examination					
				Number examined			Per cent infested						Number examined			Per cent infested		
	1920	1921	1922	1920	1921	1922	1920	1921	1922	1920	1921	1922	1920	1921	1922	1920	1921	1922
Flint corn:																		
Glenville	[1] 1.63	----	14.0	4,572	----	300	0.86	----	0.33	0.05	----	0.00	1,000	----	4,166	6.9	----	3.9
Do	----	----	3.0	----	----	823	----	----	1.90	----	----	.03	----	----	1,086	----	----	7.9
Dent corn:																		
Glenville	[1].75	6	----	2,588	100	----	.62	9.00	----	.01	0.75	----	1,000	678	----	4.3	11.8	----
Do	12.00	5	----	8,409	200	----	1.10	6.00	----	.09	.33	----	8,409	1,000	----	8.8	6.5	----
Do	----	----	1.1	----	----	157	----	----	.64	----	----	.02	----	----	1,000	----	----	.9
Sweet corn:[2]																		
Glenville	2.00	4	----	100	100	----	5.00	9.00	----	.41	1.27	----	400	1,300	----	11.7	10.1	----
Do	1.75	6	----	100	250	----	3.00	8.00	----	.12	1.08	----	200	500	----	2.5	7.4	----
Do	2.50	----	----	100	----	----	2.00	----	----	.10	----	----	300	----	----	1.7	----	----
Do	4.00	----	----	100	----	----	2.00	----	----	.11	----	----	5,074	----	----	7.5	----	----

	Flint	Dent	Sweet
Three-year average (per cent):			
Ear infestation	0.98	1.03	5.46
Grain injury	.044	.081	.628
Stalk infestation	5.09	7.75	7.79

[1] Experimental plat records.

[2] At roasting-ear stage of growth.

An examination of Table 7 shows that in eastern New York the corn borer as yet has caused but a very slight crop loss. Such infestation and loss as have occurred, however, indicate that in this area the three types of corn (flint, dent, and sweet) are equally susceptible. In the majority of the infested fields of this area the infestation is very sparse at present, and in many of these fields it is difficult to detect the presence of the insect.

Comparative counts of stalk infestation which were made during 1921 and 1922 in 12 average fields located within that portion of this area where the corn borer has become well established showed 9.3 per cent of stalk infestation in 1921, with an average of 2.51 larvae per infested stalk (23.3 larvae per 100 stalks); while in 1922 in the same fields 7.9 per cent of the stalks were infested, with an average of 2.38 larvae per stalk (18.8 larvae per 100 stalks). Figures are not available for the 1923 field survey in this area. A comparable survey in 30 of the same or near-by fields in 1924 showed an average stalk infestation of 15.1 per cent, containing an average of 1.6 larvae per infested stalk (24.2 larvae per 100 stalks). Examinations of the ear infestation in 8 of these sweet-corn fields, included above, showed that an average of 5.3 per cent of the ears contained the borer in these fields at the time of harvest.

WESTERN NEW YORK

The injury and loss as well as the degree of infestation have been greater in the western than in the eastern area of New York State. Table 8 gives data for the period 1920 to 1922 regarding infestation and injury to field and sweet-corn fields, selected on the basis of personal judgment of average conditions, within the area where the corn borer has become well established in western New York. Some of the smaller fields which represented the maximum infestation of the area are not included in this table.

TABLE 8.—*Extent of injury and loss caused by the European corn borer to ears, grain, and stalks of field and sweet corn in western New York, 1920 to 1922*

Locality (western New York)	Acreage of fields examined			Ear examination						Per cent of grain injured or destroyed on ears examined			Stalk examination					
				Number examined			Per cent infested						Number examined			Per cent infested		
	1920	1921	1922	1920	1921	1922	1920	1921	1922	1920	1921	1922	1920	1921	1922	1920	1921	1922
Flint corn:																		
Silver Creek	----	----	6. 5	----	----	500	----	----	4. 4	----	----	1. 20	----	----	500	----	----	31. 2
Dent corn:																		
Hanover	4. 00	----	----	200	----	----	12. 0	----	----	0. 37	----	----	300	----	----	71	----	----
Silver Creek	3. 50	----	10. 0	200	----	500	1. 5	----	1. 4	. 04	----	. 07	300	----	1, 000	19	----	19. 7
Indian reservation	----	----	22. 0	----	----	1, 000	----	----	1. 9	----	----	. 06	----	----	1, 000	----	----	22. 6
Silver Creek	----	----	1. 5	----	----	200	----	----	1. 0	----	----	. 11	----	----	200	----	----	15. 5
Do	----	----	6. 0	----	----	500	----	----	. 4	----	----	. 06	----	----	500	----	----	13. 0
Do	----	----	5. 0	----	----	500	----	----	. 8	----	----	. 04	----	----	500	----	----	13. 6
Do	----	----	5. 0	----	----	500	----	----	1. 2	----	----	. 12	----	----	500	----	----	13. 2
Do	----	----	2. 0	----	----	500	----	----	1. 4	----	----	. 09	----	----	500	----	----	9. 6
Do	----	----	8. 0	----	----	500	----	----	. 2	----	----	. 01	----	----	500	----	----	1. 4
Do	----	----	2. 0	----	----	500	----	----	. 2	----	----	. 00	----	----	500	----	----	3. 6
Do	----	----	2. 0	----	----	500	----	----	. 6	----	----	. 01	----	----	500	----	----	4. 2
Do	----	----	4. 0	----	----	500	----	----	. 4	----	----	. 01	----	----	1, 000	----	----	3. 5
Sweet corn:[1]																		
Hanover	. 25	----	----	100	----	----	22. 0	----	----	1. 14	----	----	100	----	----	45	----	----
Silver Creek	----	1. 0	. 1	----	150	100	----	16. 0	3. 0	----	2. 32	. 14	----	150	100	----	78	16. 0
Do	----	----	5. 0	----	----	500	----	----	4. 2	----	----	1. 01	----	----	500	----	----	37. 2
Do	----	----	2. 0	----	----	500	----	----	1. 4	----	----	. 71	----	----	500	----	----	27. 4
Do	----	----	4. 0	----	----	1, 000	----	----	2. 6	----	----	. 46	----	----	1, 000	----	----	29. 1
Do	----	----	1. 0	----	----	500	----	----	3. 2	----	----	1. 02	----	----	500	----	----	16. 4
Do	----	----	3. 0	----	----	1, 000	----	----	2. 7	----	----	. 89	----	----	1, 000	----	----	22. 7
Do	----	----	1. 0	----	----	200	----	----	. 5	----	----	. 09	----	----	200	----	----	8. 0
Do	----	----	5. 0	----	----	1, 000	----	----	5. 2	----	----	1. 64	----	----	1, 000	----	----	44. 9
Do	----	----	6. 0	----	----	1, 000	----	----	. 7	----	----	. 04	----	----	1, 000	----	----	8. 9
Do	----	----	3. 0	----	----	500	----	----	. 4	----	----	. 07	----	----	1, 000	----	----	3. 5

	Flint	Dent	Sweet
Three-year average (per cent):			
Ear infestation	4. 4	1. 33	3. 18
Grain injury	1. 2	. 06	. 75
Stalk infestation	31. 2	14. 40	23. 90

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[1] At roasting-ear stage of growth.

An examination of Table 8 shows that in western New York the corn borer is now causing appreciable injury to all types of corn, and that while the present severity of the infestation is not comparable to that existing in New England, the degree of infestation is such that serious losses may develop in the near future, unless measures are taken to keep the insect in check.

The comparative field counts of stalk infestation which were made in 1921 and 1922 in 8 fields, selected on the basis of personal judgment of average conditions, within the worst infested portion of the western New York area, showed that 26.2 per cent of the stalks were infested in 1921, with an average of 3.33 larvae per infested stalk (87.2 larvae per 100 stalks), while in 1922 in the same fields 18.9 per cent of the stalks were infested, with an average of 1.76 larvae per infested stalk (33.3 larvae per 100 stalks.) Comparable figures for the 1923 field survey show that in 30 fields, in the same area where the 1921 and 1922 surveys were conducted, there were an average of 15.2 per cent of the stalks infested, containing an average of 1.3 larvae per infested stalk (19.8 larvae per 100 stalks), while in 1924 there were an average of 27.8 per cent of the stalks infested, in 36 of the same or near-by fields surveyed in 1923, containing an average of 2.7 larvae per infested stalk (75.1 larvae per 100 stalks). Examinations for ear infestation in field and sweet corn in this area during 1923 showed that an average of 5.5 per cent of the ears were infested in 19 of the fields mentioned previously and also including sample examinations of the sweet-corn ears brought to two canning factories. A similar examination of the ears from the 36 fields surveyed in 1924, and from three canning factories, revealed that 9 per cent of the ears, on an average, contained the borer. Sample examinations of 2,700 sweet-corn ears delivered to a canning factory at Silver Creek, N. Y., during 1924 revealed that 11.9 per cent of the ears examined contained the borer.

The unusual abundance of the corn ear worm in both the eastern and western New York areas during 1921 rendered it difficult to obtain accurate records of grain injury which could be attributed solely to the corn borer.

Ohio and Michigan

In Ohio and Michigan there has been very little economic loss caused by the corn borer to the close of 1924. There was, however, a widespread dispersion of the pest in this area during 1924, accompanied by an increase in intensity which amounted to 258 per cent when compared to conditions existing in 1923. Should the rate of annual increase which prevailed during 1923 and 1924 be continued, it appears reasonable to forecast that appreciable losses will become general in this area in the near future, especially since similar developments in the older area of infestation across Lake Erie in Ontario have led to severe losses to all types of corn under similar cultural conditions to those prevailing in Ohio and Michigan. During 1923 a survey of 133 fields of Ohio and Michigan revealed an average stalk infestation of 1.83 per cent, with an average of 1.41 larvae per infested stalk or 2.58 larvae per 100 stalks. These fields were selected throughout the area as representing average conditions according to the personal judgment of the field worker. A similar field survey in 241 fields of this area during 1924 showed an average stalk infestation of 5.28 per cent, with an average of 1.75 larvae per infested stalk, or 9.24 larvae per 100 stalks. Maximums were recorded of 52 per cent in stalk infestation of sweet corn and 33 per cent stalk infestation in dent field corn during 1924, as compared to a maximum of 17 per cent in 1923.

DISTRIBUTION OF GRAIN INJURY ON INFESTED EARS

In making detailed counts of the grain injury on ears damaged by *P. nubilalis*, it was noted that while in general the greater proportion of this injury occurred to the kernels on the tip of the ear, the injury was also well distributed on the side and butt of the ear. In the majority of the lots of ears examined the total injury to the butt and side kernels nearly equaled, and sometimes exceeded, the injury suffered by the tip kernels, as will be seen in Tables 9 and 10. The tip is here considered to be the upper third of the ear, the side is considered to be the middle third, and the base the lower third. Table 9 shows the distribution of the grain injury on the infested ears of flint, dent, and sweet corn which have been previously mentioned under Table 5.

TABLE 9.—*Distribution of grain injury caused by European corn borer on infested ears (three-year average from experimental plats)*

Type of corn	Total ears examined	Per cent of ears infested	Distribution of grain injury on infested ears (per cent)[1]		
			Butt	Side	Tip
Flint	900	86.7	17.58	29.67	52.75
Dent	1,250	74.6	19.05	19.05	61.90
Sweet	5,500	57.1	13.89	22.22	63.89
Average			15.48	22.80	61.72

[1] These percentages do not refer to the total per cent of grain injury on the butt, side, and tip; they show only the relative proportions of injury to these three parts of the ears.

That the distribution of grain injury on the ears is influenced by the severity of the infestation, was demonstrated during 1922 in the presence of a more severe infestation than during the preceding two years. Table 10 shows data on this point as taken from records of ear examinations in the 1922 experimental plats of flint, dent, sweet, and pop corn in New England.

TABLE 10.—*Distribution of grain injury caused by the European corn borer on infested ears from experimental plats of 1922*

Type of corn	Total ears examined	Per cent of ears infested	Distribution of grain injury on infested ears (per cent)[1]		
			Butt	Side	Tip
Flint	50	100	31.00	22.89	46.10
Dent	100	100	20.79	30.81	48.40
Sweet	1,300	74	23.46	29.18	47.36
Pop	50	100	24.34	26.46	49.20
Average			23.58	28.93	47.47

[1] These percentages do not refer to the total per cent of grain injury on the butt, side, and tip; they show only the relative proportions of injury to these three parts of the ears.

EFFECT OF INJURY TO CORN INTENDED FOR SEED

It has been shown by Brown (*9*) that the mutilation of corn kernels does not necessarily prevent the production of normal plants by these mutilated kernels when used for seed, although the growth and yield of plants produced by such kernels may be less than from uninjured seed. The proportion of "injured" kernels shown in Tables 5 to 10 which could be used as seed, or as food, was very small, however, and was more than counterbalanced by the rotting of adjacent uninjured kernels on the cob, caused by infection from the injured kernels (not shown on the records of grain injury). Moreover, the mutilation of the kernels by *P. nubilalis*, when such kernels were not completely destroyed, was usually confined to the seed coats and endosperms. According to Brown (*9*) the injury to these portions of the kernels has a greater effect on the reduction of yield than injury to the germ.

EFFECT OF STALK INJURY

With respect to the stalk infestation and the consequent indirect injury and loss which such infestation causes to the ears and grain, it is difficult to assign any definite and uniform degree of economic importance to the figures pertaining to this factor as shown in the preceding tables, since the percentage of stalks infested, or broken over, does not in every instance have a distinct bearing upon the reduction in yield of grain or fodder. A high percentage of infested or broken-over stalks does not always mean severe damage to the ears and grain, because the principal injury and breaking over may occur late in the development of the plant, so that the grain may reach practically normal maturity in the case of field corn, or the ears of sweet corn may reach the roasting-ear stage before being seriously injured by the larvae.

Definite relation between the percentage of infested stalks and the percentage of broken-over stalks seldom was found because the amount of breaking over, except in instances of very severe infestation, depends to a considerable extent upon the size of the stalks of the variety attacked, and upon the occurrence of heavy wind or rainstorms after the injury takes place. Large heavy-stalked varieties will sometimes withstand considerable infestation without breaking over or showing an appreciable effect upon the ears or grain, whereas small-stalked varieties are much more susceptible to such injury as a result of the tunneling of the borers, and if severely attacked early in their development, extensive curtailment of grain production may result.

EFFECT OF INJURY TO STALKS UPON THE NUMBER AND WEIGHT OF EARS

In attempting to obtain information regarding the effect of stalk injury upon the number and weight of ears produced by such stalks, an important handicap has been encountered because of the fact that in fields where stalk infestation was severe enough to exert an appreciable effect upon ear production, noninfested stalks which could be used as a means of comparison were wanting. It is obvious that for satisfactory information on this point the infested and noninfested plants should be of the same variety and type, planted at the same time, and grown under identical soil and other cultural conditions. Therefore, it became necessary to make a comparative examination of this character in the same field, and to select a field for this purpose which showed a relatively light infestation in order to secure noninfested stalks.

Table 11 gives results from two fields of Longfellow flint field corn in which the ears and nubbins were removed and weighed from an equal number of severely infested and noninfested stalks. In field No. 1, located at Stoneham, Mass., 78 per cent of the stalks and 66 per cent of the ears were infested, with a total grain injury of 2.2 per cent. In field No. 2, located at Wakefield, Mass., practically 100 per cent of the stalks and 39 per cent of the ears were infested, with a total of 1.9 per cent grain injury. In this field it was possible to find a sufficient number of noninfested stalks to serve as a comparison.

TABLE 11.—*Effect of injury caused by the European corn borer to stalks upon the number and weight of field-corn ears*

Location (Mass.)	Total stalks examined in each lot	Infested stalks			Noninfested stalks			Loss in ears		Loss in weight	
		Number of ears	Number of nubbins	Weight of ears and nubbins (lbs.)	Number of ears	Number of nubbins	Weight of ears and nubbins (lbs.)	Number	Per cent	Pounds	Per cent
Stoneham	100	98	12	47.50	99	13	51.50	1	1.01	4.00	7.76
Wakefield	50	44	8	18.00	51	4	25.75	7	13.73	7.75	30.10
Total	150	142	20	65.50	150	17	77.25	8		11.75	
Average									5.33		15.21

From Table 11 it appears that in the two fields examined the number of ears from the noninfested stalks exceeded those from the severely infested stalks by 5.33 per cent, while weight of the ears and nubbins from the noninfested stalks exceeded that of the infested stalks by 15.21 per cent. The "severely infested" stalks used as a basis of comparison were selected with a view to approximating average conditions in fields sustaining maximum infestation, and the losses shown in Table 11 may therefore be taken as indicative of actual loss occasioned by borer injury to the stalks. The percentage of loss due to prevention of ear production and reduced weight of ears and nubbins, as shown, undoubtedly is exceeded in fields sustaining maximum infestation, but in the absence of accurate means of calculating such losses no figures can be given. It is in this class and from this cause that the major portion of the gross damage by the corn borer occurs, as will be apparent by comparing the figures showing direct grain injury with the figures showing indirect grain loss through the prevention and reduction of ear (grain) formation.

EFFECT OF INJURY TO STALKS UPON NUMBER OF MARKETABLE EARS PRODUCED BY SWEET CORN

A belief exists among growers of sweet corn in Massachusetts that severe injury to the plants by the corn borer results in a decrease in the number of marketable ears produced and an increase in the proportion of nubbins. In order to investigate this theory, a comparison was made between the production of ears and nubbins by infested and noninfested plants growing in each of seven fields. Examinations were made in representative parts of each field, all the plants in a section of row being examined. The results are shown in Table 12.

TABLE 12.—*Effect of injury to stalks of sweet corn upon the number of marketable ears produced*

Town (Mass.)	Field No.	Variety	Per cent stalks infested	Per cent ears infested	Total plants examined in each lot	Infested plants		Noninfested plants		Loss in marketable ears	
						Number of marketable ears	Number of nubbins	Number of marketable ears	Number of nubbins	Number	Per cent
Saugus	1	Golden Bantam	58	18	25	41	32	49	26	8	16.33
Medford	2	Early Crosby	35	17	25	27	35	39	28	12	30.77
Do	3	Quincy Market	47	11	25	47	35	47	40	0	0.00
Do	4	Golden Bantam	100	52	200	190	130	263	129	73	27.76
Saugus	5	do	86	66	200	110	92	193	52	83	43.01
Do	6	Golden Giant	94	36	200	232	92	248	80	16	6.45
Do	7	Golden Dawn	63	37	200	236	107	264	124	28	10.61
Total					875	883	[1] 523	1,103	479	220	
Average											19.94

[1] Increase in nubbins of infested plants equals 9.1 per cent.

All of these fields were of the early plantings and the infestation consisted almost entirely of first-generation individuals. The data for fields 1 to 3 were obtained in 1921, and for fields 4 to 7 in 1922. In field 4 it was necessary to include a number of slightly infested plants among the "noninfested" group owing to the difficulty of finding strictly noninfested plants.

Table 12 indicates that in the fields under consideration there was a reduction of 19.94 per cent in the number of marketable ears produced by infested plants as compared with the noninfested plants in the same fields. An increase of 9.19 per cent of nubbins was noted as a result of corn-borer injury to the plants.

In fields of sweet corn showing maximum infestation (figs. 24 and 25) the reduction in marketable ears was much more pronounced than these figures indicate. In such areas, however, practically 100 per cent of the plants were badly infested, which fact did not permit an accurate comparison between ear production of infested and noninfested plants.

PERCENTAGE OF BROKEN-OVER STALKS AND EAR STEMS DUE TO LARVAL INJURY

Reference has previously been made to the breaking over of stalks and ear stems as a result of the tunneling of corn-borer larvae. Although the effect upon grain formation of such breaking over is exceedingly variable, and no definite economic importance can be assigned to this type of injury, it was thought desirable to present figures showing the extent of its occurrence. The counts shown in Table 13 were obtained from examinations of average stalks and ears in the experimental plats of flint and dent corn at Medford, Mass., during 1920.

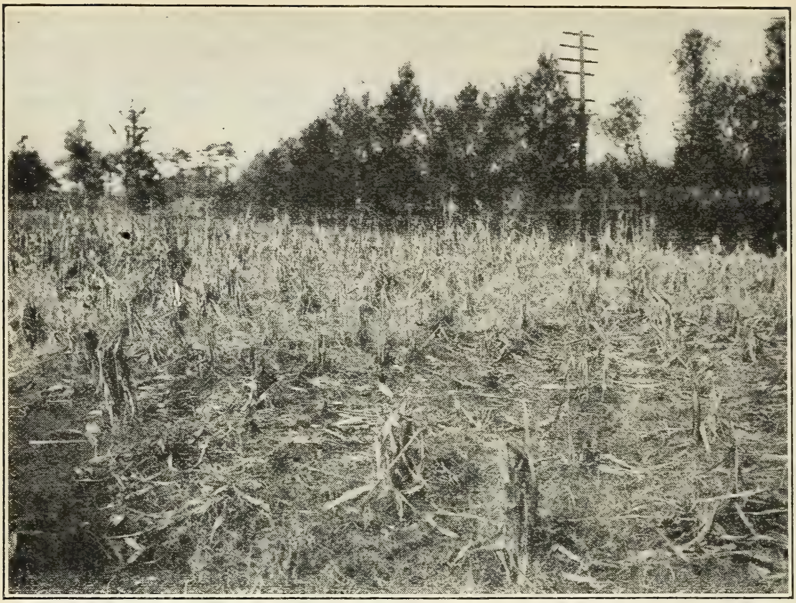

FIG. 24.—General view of a field of sweet corn ruined by European corn borer. No marketable ears were obtained from this field. Medford, Mass., September, 1922

TABLE 13.—*Per cent of broken-over stalks and ear stems due to larval injury by the European corn borer*

Type of corn	Number of plats	Total stalks	Per cent stalks infested	Per cent stalks broken over at harvest		Total ears	Per cent ear stems infested	Per cent ear stems broken over at harvest
				Below ear	Above ear			
Flint	4	147	100	10.8	16.3	110	72.7	19.9
Dent	4	140	100	22.8	29.9	78	85.9	2.6
Total		287				188		
Average			100	16.7	22.9		78.2	12.8

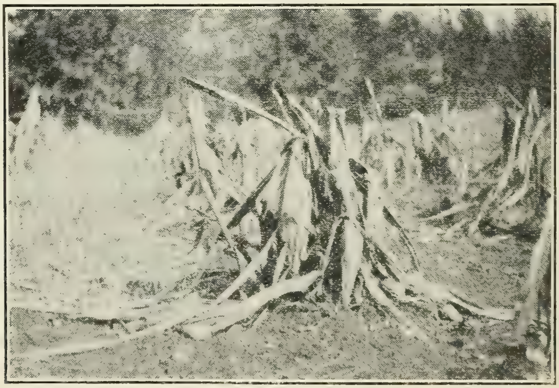

FIG. 25.—"Close-up" of hill of sweet corn ruined by European corn borer. No marketable ears were produced in this hill. Medford, Mass., September, 1922

Table 13 shows that as a result of larval injury, when 100 per cent of the stalks were infested at harvest, an average of 16.7 per cent of these stalks were broken over below the ear and an average of 22.9 per cent were broken over above the ear, thus making a total average of 39.6 per cent of the stalks broken over at this time. The examination of 188 ears borne by the 287 plants examined revealed an average of 78.2 per cent with infested ear stems and an average of 12.8 per cent of the ear stems broken over before harvest.

LENGTH AND VOLUME OF TUNNEL IN STALK MADE BY EACH LARVA

In order to obtain information relative to the length and volume of each tunnel bored out or consumed by each larva, measurements were made of individual tunnels in 35 stalks of sweet corn and in 6 stalks of dent corn, each of which was inhabited by a single larva. Care was taken in the selection of these stalks to ascertain that each tunnel was made by the larva then inhabiting it. It was not possible in every instance, however, to determine whether the larva in its younger stages had or had not fed upon the exterior of the same or adjoining plants before starting its tunnel in the stalk. The results of these measurements are shown in Table 14.

TABLE 14.—*Length and volume of tunnel in stalk made by each European corn borer larva*

Type of corn	Number of stalks	Average length of each tunnel in inches	Average volume of each stalk (cubic inches)	Average volume of each tunnel (cubic inches)	Average per cent loss in volume to each stalk
Sweet	35	9.036	7.0441	0.2492	3.538
Dent	6	6.125	16.5263	.1690	1.022
Average		8.610			2.816

From Table 14 it is seen that the average length of the tunnel made by each larva under observation equaled 8.61 inches, and that there was an average of 3.489 per cent loss in volume caused by the boring and feeding of each larva.

EXTENT AND EFFECT OF BROKEN-OVER TASSELS

Counts made in badly infested cornfields have shown as many as 89.9 per cent of the tassels broken over. Many ears of corn from fields thus affected are abnormally small in size, or lacking in proper grain formation, even though they are not directly injured by the larvae, but it has been difficult definitely to assign the lack of proper fertilization as a reason for this condition, because such ears are usually borne by plants which have been otherwise seriously injured by the insect. When the tassel breaks over early in its development there results a loss of pollen, but this type of injury or mutilation has been considered by corn technologists as unimportant, even where a large proportion of the tassels are thus affected. The remaining uninjured tassels are said to furnish sufficient pollen for the proper fertilization of the plants in the vicinity. The percentage of tassels broken over as a result of European corn borer injury during 1920 and 1921 in certain fields of sweet, flint, dent, fodder, and pop corn, representing ordinary conditions in the heavily infested portion of New England, is shown in Table 15.

TABLE 15.—*Per cent of tassels broken over as a result of European corn borer injury*

Type of corn	Number of fields	Tassels counted	Tassels broken over	Per cent tassels broken over		
				Average	Maximum	Minimum
Sweet	30	11,913	3,584	30.1	89.9	1.3
Flint	16	5,428	1,412	26.0	35.4	2.7
Dent [1]	10	6,700	992	14.8	16.5	8.2
Fodder	2	7,238	1,204	16.6	22.1	9.9
Pop	1	500	227	45.4		
Total		31,779	7,419			
Average				23.3		

[1] Limited to experimental plat counts. No dent corn grown for grain within the Boston area.

Table 15 shows that the average of broken-over tassels as a result of larval injury ranged from 14.8 to 45.4 per cent in the different types of corn examined, with an average of 23.3 per cent of the tassels in the entire lot. In fields representing maximum infestation the percentage of broken-over tassels was much higher than these figures indicate.

EXTENT OF INJURY TO VEGETABLES, FLOWERS, AND FIELD CROPS

NEW ENGLAND

The extent of injury and loss to vegetables, flowers, and field crops in New England, caused by the corn borer, has not been severe in most instances, seldom exceeding 5 per cent of the total value of any crop. There has been, however, a very considerable increase each year in the infestation of these crops. In 1917, when the field investigations on the corn borer were started, it was difficult to find infestations in crops other than corn, although according to Vinal (*70*) certain of the flowers, notably dahlias, were occasionally attacked. Infestation has progressed to a point where in 1921 and 1922 most commercial fields of the more susceptible vegetable and flower crops, such as rhubarb, beets, celery, beans, peppers, dahlias, asters, and gladioli, were infested in localities in Massachusetts where the corn borer has become at all numerous. The infestation in some of the beet and celery fields during 1922 was especially pronounced and led the growers of these crops to view with apprehension the increased damage to these vegetables.

Formerly most of the infestations in vegetables and flowers were confined to weedy fields, and along field borders where the plants were growing among or in close proximity to infested weeds or corn, but during 1922 these crops were commonly subjected to appreciable infestation and injury even in fields that were kept free of weeds and isolated from areas of susceptible weeds or corn. The following discussion applies principally to conditions existing during 1921 and 1922 with respect to the more important and susceptible economic hosts of the corn borer. During 1923 and again in 1924 a marked reduction occurred in the extent of infestation and injury to vegetables, flowers, and field crops, a reflection of the general decrease in intensity which developed in the New England area during those two years.

RHUBARB

Rhubarb has been infested to a greater extent than any other vegetable or garden crop excepting sweet corn. The large leaves of this plant are particularly attractive to the adults as a place for concealment and subsequent deposition of eggs. Later the larvae infest the leafstalks and veins of the leaves. In two fields where detailed examinations were made during June, 1922, an average of 2.5 egg clusters per plant were found on the leaves, with occasional egg clusters on the leafstalks. The majority of the fields in the Boston area contained from 5 to 40 per cent of infested stalks during 1921 and 1922. In fields representing maximum infestation as high as 75 per cent of the stalks were infested. Most of the severe injury occurred after the close of the commercial season for harvesting rhubarb, and the growth of the injured plants did not appear to be seriously affected by it. The necessity of discarding infested stalks in preparation for market caused appreciable loss in fields severely infested early in the season.

BEETS

The extent of infestation in beets was very nearly equal to that mentioned for rhubarb. Most of the injury to beets was confined to the leafstalks (fig. 26), although during 1922, when the increase of infestation in this vegetable was most marked, a considerable number of the beet roots, amounting in some instances to 5 per cent of the total in the worst infested fields, were found to contain the borer. Except in instances where several of the leafstalks were entered by the borer, the injury did not appear seriously to interfere with the growth of the plant. The fact that the injured leafstalks must be removed in preparing for market as bunched beets, affected the appearance and consequently the price of the product from fields where a high percentage of the plants were affected. Table 16 gives results of examinations in average beet fields of the Boston area taken on various dates distributed throughout the season when the plants were ready for market.

TABLE 16.—*Extent of injury and infestation by the European corn borer in beets, New England area, 1922*

Field No.	Locality (Massachusetts)	Date examined (1922)	Number of plants	Plants showing injury		Plants containing larvae		Larvae per infested plant	
				Number	Per cent	Number	Per cent	Average	Maximum
1	Arlington	Sept. 20	100	10	10.0	8	8.0	1.00	1
[1] 2	Do	June 30	600	35	5.8	23	3.8	1.00	1
[1] 3	Medford	July 11	100	39	39.0	31	31.0	1.32	3
[1] 4	Do	do	200	64	32.0	49	24.5	1.59	8
[1] 5	Do	July 10	100	10	10.0	8	8.0	1.12	2
[1] 6	Saugus	July 13	100	25	25.0	18	18.0	1.00	1
7	Do	Oct. 4	100	61	61.0	57	57.0	1.98	4
[1] 8	Somerville	July 17	100	9	9.0	8	8.0	1.25	3
9	Do	Oct. 5	100	71	71.0	66	66.0	2.95	14
[1] 10	Watertown	July 17	500	126	25.2	113	22.6	1.24	4
11	Do	Sept. 30	200	0	0.0	0	0.0	0.00	0
[1] 12	Winchester	July 12	100	48	48.0	41	41.0	1.53	6
13	Woburn	Sept. 28	100	59	59.0	59	59.0	1.79	6
[1] 14	Do	July 11	100	34	34.0	27	27.0	1.96	7
	Total		2,500	591		508			
	Average				23.6		20.3	1.69	

---

[1] Infestation chiefly by first generation.

Table 16 shows that in the 14 fields under observation an average of 23.6 per cent of the beet plants were injured and 20.3 per cent of the plants actually contained the borer at the time of examination. The difference between the percentage of plants showing injury and the percentage actually containing the borer at the time of examination is due to the migration of the borers from some of the badly injured plants to other plants furnishing a fresher food supply. There were on an average 1.69 borers per infested plant.

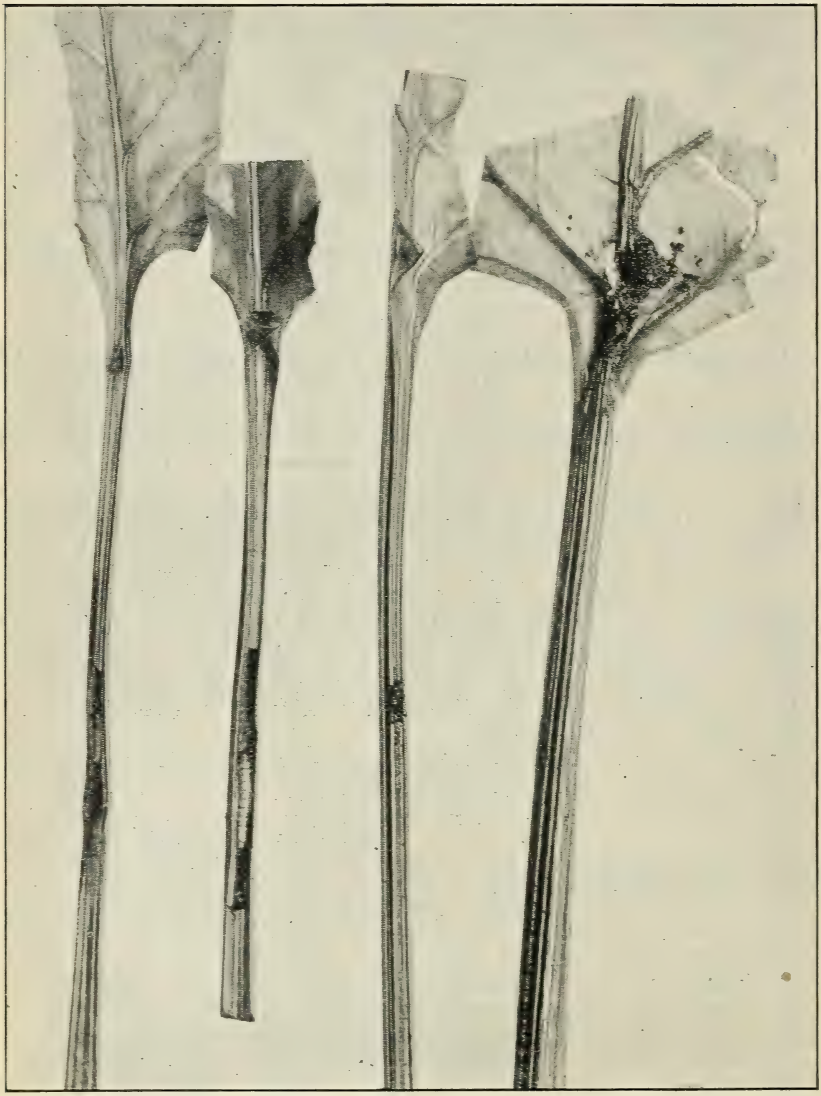

FIG. 26.—Beet stems injured by larvae of the European corn borer

In some of the smaller fields and in home gardens representing maximum infestation the beet crop was abandoned, owing to the injury to the roots and leafstalks.

CELERY

The infestation in celery has been general for the last two years, and, although the injured portion of the plants could usually be removed with very little commercial injury to the remainder of the plant (fig. 27), there was an appreciable loss ranging from 5 to 10 per cent of the total value of the crop in the worst infested fields, owing to the necessity of discarding severely injured plants. During 1922 the infestation in celery fields showed a considerable increase as compared with the previous year. Certain fields of celery, which were kept cleanly cultivated and isolated from corn or other susceptible plants, showed a severe and uniform infestation. In Table 17 are given figures relating to field examinations made in celery fields of the Boston area showing average infestation.

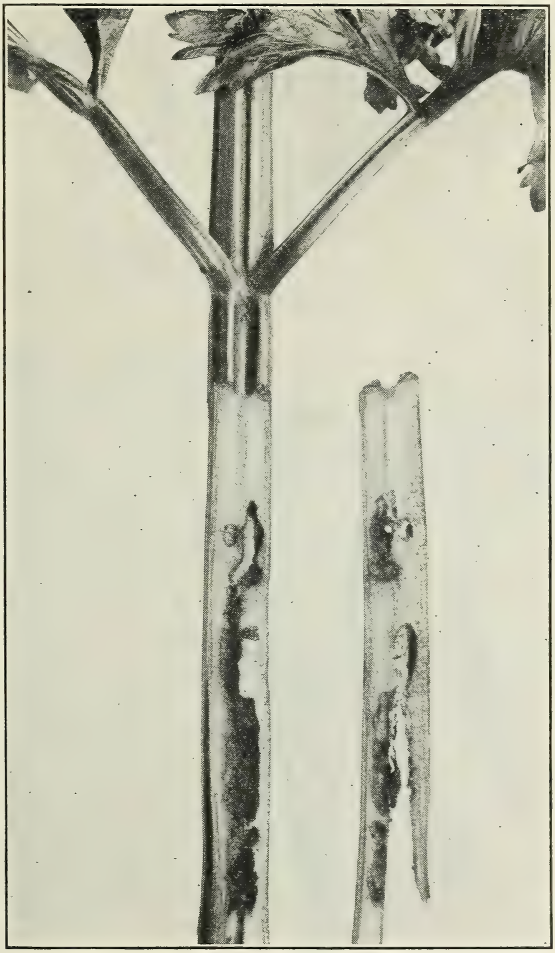

FIG. 27.—Stalks of celery sectioned to show injury by European corn borer

TABLE 17.—*Extent of injury and infestation by the European corn borer in celery, New England area, 1922*

Field No.	Locality (Mass.)	Date examined (1922)	Plants showing injury		Plants containing larvae		Larvae per infested plant	
			Number[1]	Per cent	Number[1]	Per cent	Average	Maximum
1	Arlington	Sept 25	8	1.6	2	0.4	1.00	1
2	Do	Sept. 26	32	6.4	13	2.6	1.00	1
3	Do	Sept. 20	26	5.2	9	1.8	1.30	3
4	Do	Oct. 5	151	30.2	42	8.4	3.52	8
5	Do	Oct. 5	140	28.0	45	9.0	2.93	10
6	Belmont	Sept. 26	14	2.8	3	.6	1.00	1
7	Do	Sept. 26	9	1.8	5	1.0	1.00	1
8	Medford	Sept. 26	78	15.6	32	6.4	1.37	3
9	Somerville	Oct. 5	38	7.6	16	3.2	1.50	4
10	Watertown	Sept. 30	3	.6	0	.0	.00	0
11	Do	Sept. 30	8	1.6	2	.4	1.00	1
12	Woburn	Sept. 28	120	24.0	69	13.8	1.32	3
	Total		627		238			
	Average			10.4		3.96	2.00	

[1] 500 plants examined in each field.

Table 17 shows that in the 12 fields under observation an average of 10.4 per cent of the celery plants showed injury and that an average of 3.96 per cent of the plants contained the borer at the time of the examination, with an average of two larvae per infested plant.

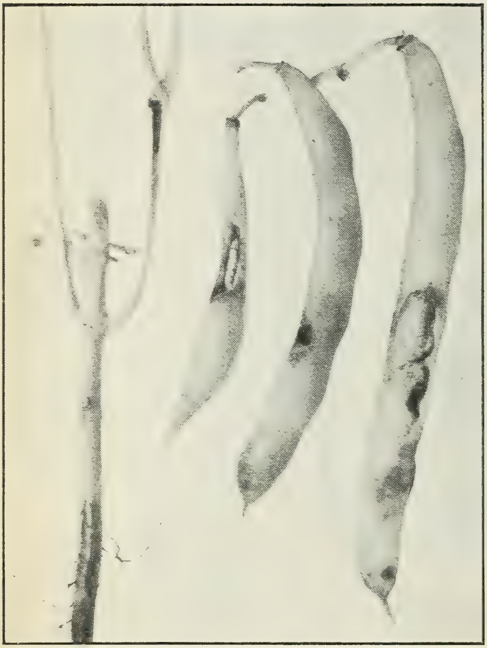

FIG. 28.—Green beans, showing the work of European corn-borer larvae

BEANS

Injury to beans (fig. 28) was confined principally to the stalks with an occasional infestation in the pods. Infested pods were usually unfit for sale, but less than 1 per cent of the total pods were affected in any of the commercial fields examined. In instances of severe injury to the stalks, the affected portions broke over and resulted in a decreased yield of pods. In some of the small home gardens as high as 100 per cent of the plants and 22 per cent of the pods were infested. Field counts made in 10 bean fields of the Boston area, showing average infestation, are given in Table 18.

In the bean fields under observation (Table 18) an average of 3.55 per cent of the plants showed injury and 3.22 per cent contained larvae, with an average of 1.18 larvae per infested plant.

TABLE 18.—*Extent of injury and infestation by the European corn borer in beans, New England area, 1922*

Field No.	Locality (Mass.)	Date examined (1922)	Number of plants	Plants showing injury		Plants containing larvae		Larvae per infested plant	
				Number	Per cent	Number	Per cent	Average	Maximum
1	Medford	July 11	200	11	5.5	5	2.5	1.0	1
2	Do	July 12	500	20	4.0	19	3.8	1.3	4
3	Do	July 13	200	30	15.0	30	15.0	1.3	3
4	Do	July 13	200	15	7.5	14	7.0	1.2	2
5	Saugus	July 13	500	8	1.6	8	1.6	1.0	1
6	Somerville	July 17	200	7	3.5	7	3.5	1.0	1
7	Winchester	July 12	200	1	.5	1	.5	1.0	1
8	Do	July 12	300	4	1.3	3	1.0	1.0	1
9	Woburn	July 12	200	0	.0	0	.0	.0	0
10	Do	July 11	200	0	.0	0	.0	.0	0
	Total		2,700	96		87			
	Average				3.55		3.22	1.18	

SPINACH

The occurrence of corn-borer egg clusters on the leaves of spinach was very general during 1922–23 in the Boston area. In nearly every spinach field examined, egg clusters were found on the leaves, usually involving less than 1 per cent of all the plants. Usually the spinach was harvested before the larvae hatched or became large enough to injure the plants, but where harvesting was delayed, borers were occasionally found in the leaf stems. No commercial injury resulted to spinach in any instance under observation.

PEPPERS

The stalks and fruits of sweet and hot varieties of peppers are very susceptible to corn-borer attack. In the Boston area during September and October, 1922, every field of peppers examined showed conspicuous evidence of damage through the medium of broken-over plants. In three fields where detailed examinations were made, the percentage of plants injured ranged from 18 to 97, and 52 to 76 per cent of the fruits had been injured by the borer. In these pepper fields, in instances where the stalks became broken over before the fruit had fully developed, there occurred a cessation of growth to the fruit which caused a reduction in yield of marketable peppers. Much of the infested fruit was unfit for sale, but the proportion of actual loss from this cause varied according to the use for which the peppers were intended.

POTATO

The stalks of potato have commonly been found infested (fig. 17) in Massachusetts. In two fields where detailed examinations were made during late July, 1922, an average of 18 and 62 per cent respectively of the plants were found to contain the borer. Although such injury resulted in quite an extensive breaking over of the stalks in some fields, it did not appear to affect the successful formation of tubers. No economic loss resulted in any instance under observation.

TOMATO

The stalks and fruit of tomatoes have frequently been found infested each year since 1918. Usually less than 1 per cent of the stalks or fruit have been involved in the majority of the fields examined, but in some fields during the late summer of 1922 as high as 14 per cent of the stalks and 5 per cent of the fruit were found to contain the borer. When the stalks were severely attacked early in their development, they often collapsed and fruiting was greatly reduced, or even prevented. Otherwise the growth of injured plants was not appreciably affected. Infested fruits usually were rendered unfit for sale.

SWISS CHARD

The leaf stalks of Swiss chard were commonly infested by the corn borer, and although the injured portions usually were made unfit for food, the losses have been of but little commercial importance, as this plant is grown here mainly as a kitchen-garden vegetable. During 1922 an examination of one of the larger garden plots of Swiss chard showed that 23 per cent of the leaf stalks were injured by the corn borer.

DAHLIAS

Dahlias are the most susceptible of all the flower crops. During August and September of 1922 and 1923, 100 per cent of the dahlia plants were infested in many of the commercial gardens in the Boston area, causing an estimated loss in some instances amounting to 10 per cent of the crop. Many of these plants were ruined, and the susceptibility of dahlia plants to corn-borer injury caused certain of the commercial specialists in this flower to abandon its culture. The most careful scrutiny has failed to disclose any corn-borer infestation in the dahlia tubers, but all parts of the plant above ground are liable to injury. Egg clusters were commonly found on the dahlia blooms, as well as on the leaves, during July and August, 1922. In three commercial dahlia gardens the proportion of blooms bearing egg clusters ranged from 1.4 to 19.8 per cent.

ASTERS

China or garden asters very frequently have been found infested in home gardens and commercial establishments throughout the Boston area during the period from July to September. Infestation reached a maximum of 76 per cent of the plants in small home gardens, and in one commercial establishment 86 per cent of the plants were injured. The normal development of flowers was prevented in instances where plants were severely injured at an early stage of their growth, and during 1922 many of the flowers, involving in one instance 11 per cent of the total, were also entered by borers. The estimated loss in the most heavily infested aster plantings ranged from 10 to 15 per cent of the total value of the crop.

CHRYSANTHEMUMS

The injury to chrysanthemums (fig. 29) has been confined principally to plants grown under glass for the late fall trade. Infested plants have been found each year since 1919 in the majority of the greenhouses examined in the New England area. Usually less than

1 per cent of the plants were involved, but in extreme cases as high as 20 per cent of the plants contained the borer. In 1922 an inspection was made in 30 of the larger greenhouses in eastern Massachusetts, where a total of 353,500 chrysanthemums were grown. Infestations were found in 23 of these establishments, the number of plants involved ranging from less than 1 to 9.22 per cent, with an average of 1.08 per cent for the 30 houses, at the time of examination. Many of the injured plants had been removed and discarded

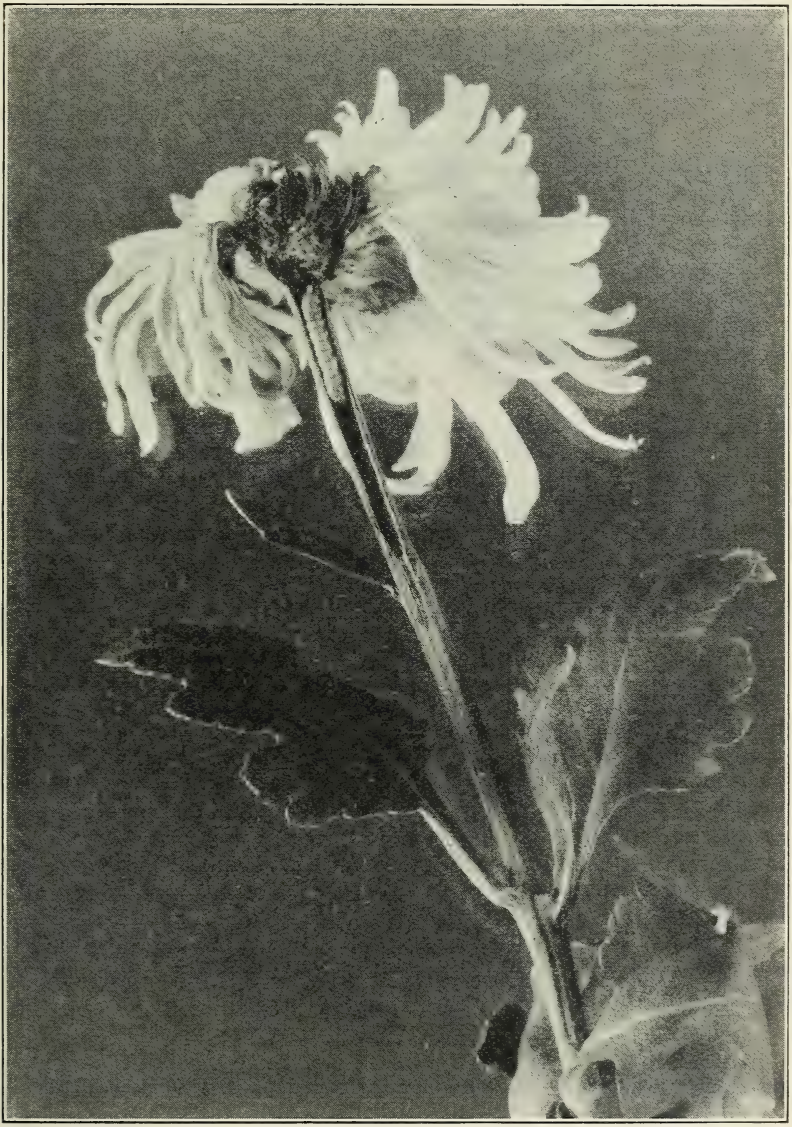

FIG. 29.—Injury to stem and flower of greenhouse chrysanthemum by European corn borer. Stem sectioned to show borers within. Melrose, Mass., November 10, 1922

before examination occurred, so the percentages given represent minimum figures. When the injury occurred in the lower part of the stems and after the plants had become fully developed, the blooms were suitable for sale. The estimated loss amounted to 6 per cent of the value of the crop during 1922 in houses showing maximum infestation.

Gladioli

The flower stalks of gladiolus plants were infested by the corn borer (fig. 19), and egg clusters have occurred on the leaves, in a few fields each year since 1918. Usually this infestation has been very sparse, but in 1919 a maximum of 6 per cent of the flower stalks were injured by the borer in two fields grown in close proximity to other infested crops. In 1921 and 1922 a scattering infestation was found in the majority of fields examined, but less than 1 per cent of the plants were involved, and the economic loss in any instance was trivial. No infestation or injury to the bulbs has been observed to date.

Zinnias

The stalks and flowers of zinnias commonly are infested by the corn borer in home gardens and small commercial establishments. During the late summer of 1922 there was a decided increase in the injury to zinnias as compared with former years, but most of this injury occurred after the better blooms had been picked, and was, therefore, of little economic importance. In many of the home gardens of the Boston area practically 100 per cent of the plants were infested, and in one instance 90 per cent of the blooms contained the borer.

Oats

The stems (culms) of oats have occasionally been found infested (fig. 18) when growing as volunteer plants and in experimental areas. This crop rarely is grown commercially within the area where the European corn borer is numerous at present. In 1921 a small experimental plat of oats was grown in close proximity to infested corn and other susceptible plants. Only a fraction of 1 per cent of the stems were infested at the time of harvest. After being cured in the usual manner, part of the straw was baled and the remainder left loose. A detailed examination of about 58,000 straws from both lots revealed that living borers were present in the baled straw at a rate of 8 borers per 100 pounds, and in the loose straw at a rate of 11 borers per 100 pounds.

Other Field Crops

In order to obtain information relative to the susceptibility and extent of injury by *P. nubilalis* to various field crops which normally are not grown to any extent in the Boston area, small plats of these crops were grown in the experimental fields at Medford, Saugus, Cambridge, Belmont, and Woburn, Mass., during the period from 1919 to 1922. Some of these crops, such as cotton and the grain sorghums, are seldom, if ever, grown in this section of the country. The more important information obtained from these plats is summarized in Table 19.

TABLE 19.—*Susceptibility and extent of injury by Pyrausta nubilalis to various field crops in experimental fields (New England, 1919 to 1922)*

Plant	Egg clusters			Larvae					
	Total plants examined	Total egg clusters found	Per cent plants bearing egg clusters	Total plants examined	Total plants found tunneled	Total plants containing larvae	Per cent plants containing larvae	Total larvae found	Average larvae per 100 plants
Millet (Japanese)	--------	--------	--------	200	64	27	13.5	38	19.0
Millet (European)	50	1	2.0	200	52	17	8.5	27	13.5
Millet (Hungarian)	50	0	0.0	200	6	1	.5	1	.5
Hemp	--------	--------	--------	10	10	10	100.0	150	1,500.0
Hegari	66	15	21.2	84	77	70	83.3	218	259.5
Feterita	115	21	16.5	343	79	56	16.3	110	32.1
Milo	142	32	14.8	420	324	254	60.4	444	105.7
Kafir	174	16	9.2	400	29	8	2.0	8	2.0
Broomcorn	282	26	8.5	450	234	191	42.4	314	69.8
Barley	50	--------	0.0	100	5	1	1.0	1	1.0
Cotton [1]	210	25	11.4	656	112	22	3.4	23	3.5
Cowpea	190	13	6.3	691	240	52	7.5	67	9.7
Sorgo	50	13	22.0	450	39	21	4.7	28	6.2
Hop (common)	18	0	0.0	12	10	3	25.0	5	41.6
Buckwheat	--------	--------	--------	200	11	11	5.5	11	5.5
Johnson grass	250	15	6.0	1,050	27	12	1.1	15	1.4
Sudan grass	25	3	12.0	50	7	5	10.0	7	14.0
Soy bean	441	2	.6	441	18	9	2.0	10	2.3
Peanut	82	1	1.2	114	11	3	2.6	3	2.6

[1] Bolls developed on plants in one plat during 1921. A count of 200 green bolls showed that 9 per cent were infested, one larva per boll. Plants killed by frost before bolls opened.

The experiments detailed in Table 19 were conducted under conditions of severe infestation, and due allowance should be made for this fact when interpreting the susceptibility of the plants listed. It is significant, however, that many of these plants which have been recorded in foreign literature as hosts of *P. nubilalis*, notably hemp (fig. 30), hops, millet (fig. 31), cotton (fig. 32), and the grain sorghums (fig. 33), were also infested by the insect in New England. This development is only indicative, of course, of the susceptibility of these plants if grown commercially in areas where two generations of *P. nubilalis* occur each year.

NEW YORK, PENNSYLVANIA, OHIO, AND MICHIGAN

There has been but very little loss or infestation to date from the work of the European corn borer in vegetables, flowers, or field crops, except corn and broomcorn, in the infested areas of New York, Pennsylvania, Ohio, and Michigan. During 1923 two fields of broomcorn, comprising a total of 12 acres, grown at Irving, N. Y., showed stalk infestations of 12.7 and 15.8 per cent, respectively. In western New York slight infestations have also been observed in commercial fields of soy beans, buckwheat, and potatoes, and in half-acre fields of European millet or proso, which was planted on two farms near Silver Creek, N. Y., to test its possible utility as a trap crop. Occasional infestations have also been observed in the stems and fruits of tomato. Occasional instances of infestation have also been observed in experimental plats of Japanese and European millet or proso, sorghum, rhubarb, kidney or wax beans, milo, soy beans, dahlias, and cosmos at Silver Creek, N. Y.

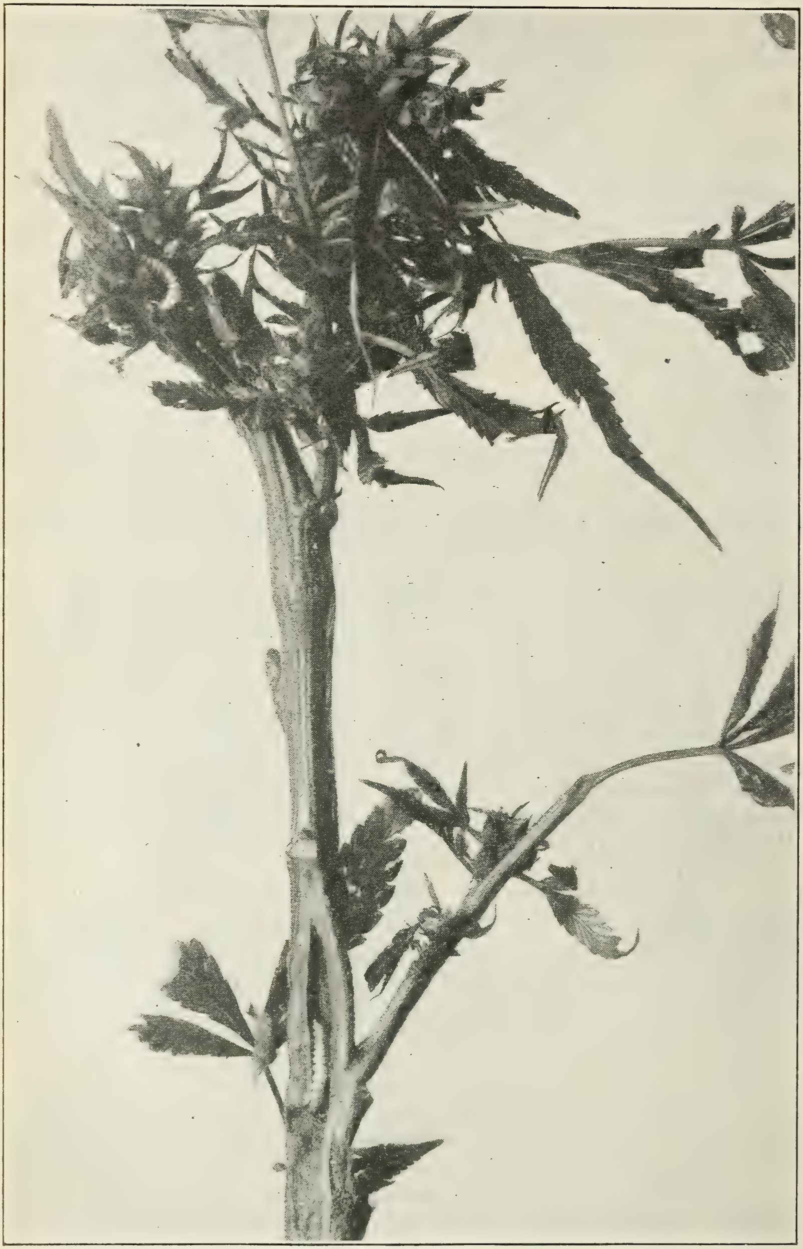

FIG. 30.—Hemp infested by European corn borer. A favorite host of the insect in the Old World

EXTENT OF INJURY AND INFESTATION IN WEEDS AND GRASSES

Injury to the weeds and wild grasses (figs. 3 to 5) serving as hosts of the European corn borer (Table 1) is not commercially important, but the infestation of such weeds and grasses affords abundant opportunity for the multiplication and spread of the pest in fields where corn or other economic plants are not grown or in cultivated fields where the borers are so numerous that they are compelled to feed upon these weeds or grasses in order to complete their growth. The infestation in such plants is most pronounced in the New England

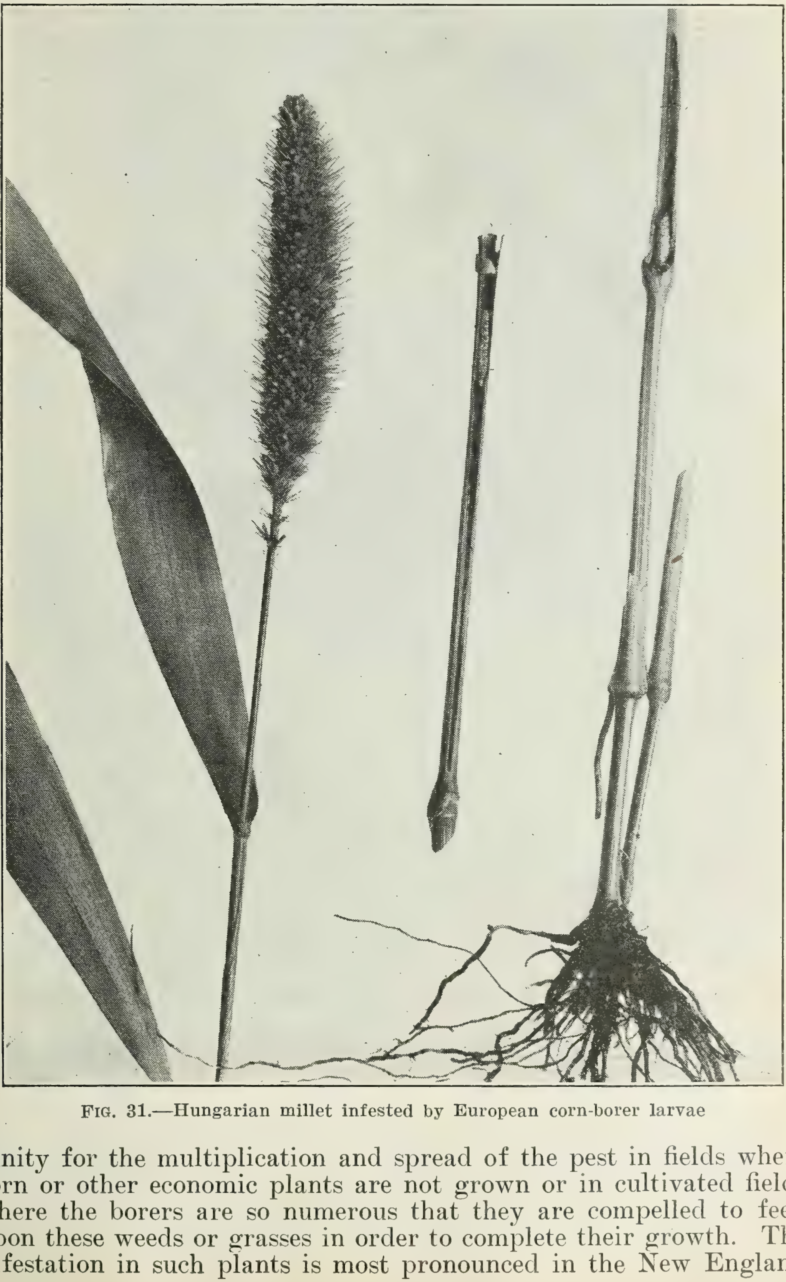

FIG. 31.—Hungarian millet infested by European corn-borer larvae

area. In the other areas of the United States where the insect is present only a slight infestation in these plants as yet has occurred.

Table 20 details field counts of infestation in 17 of the more susceptible and widely dispersed weeds and wild grasses during 1920 and 1921 in cultivated fields and waste areas, showing average infestation in that portion of the New England area where the European corn borer has become well established. It does not include small isolated patches of weeds which represented the maximum infestation. These counts were taken during the growing season at a time when the plants had reached full size, and while larvae contained in each plant examined apparently were feeding therein. It was not possible in every instance, however, to ascertain whether each individual was actually feeding or was using the plant as a shelter.

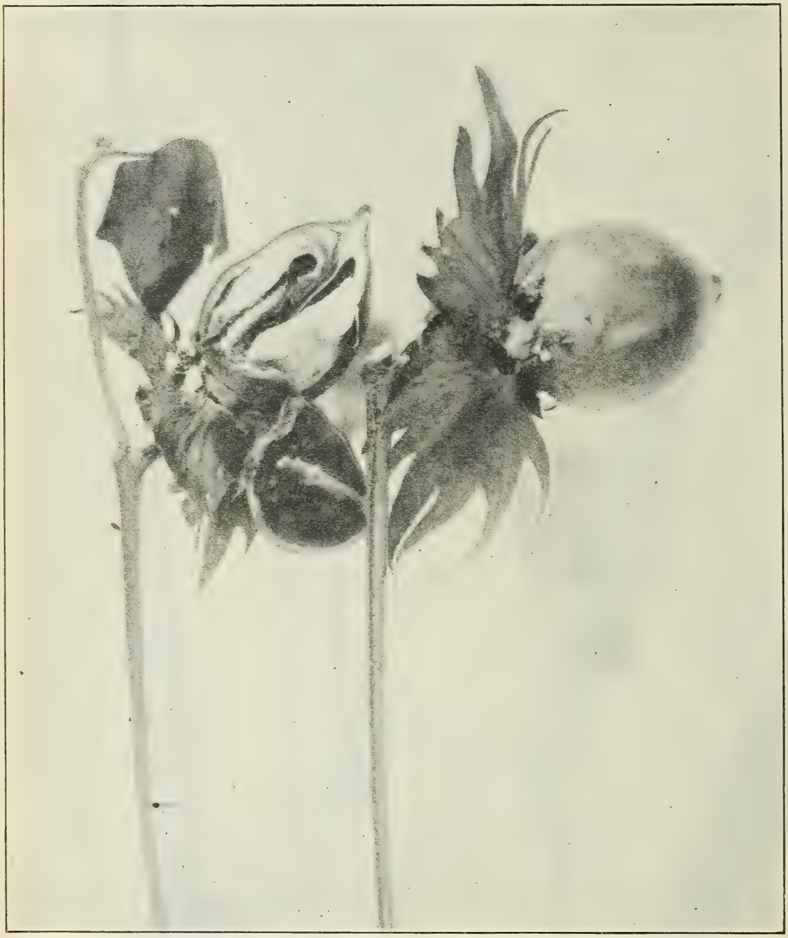

FIG. 32.—Typical injury to bolls of cotton by European corn borer. Cotton grown experimentally at Medford, Mass. Photo taken September, 1921

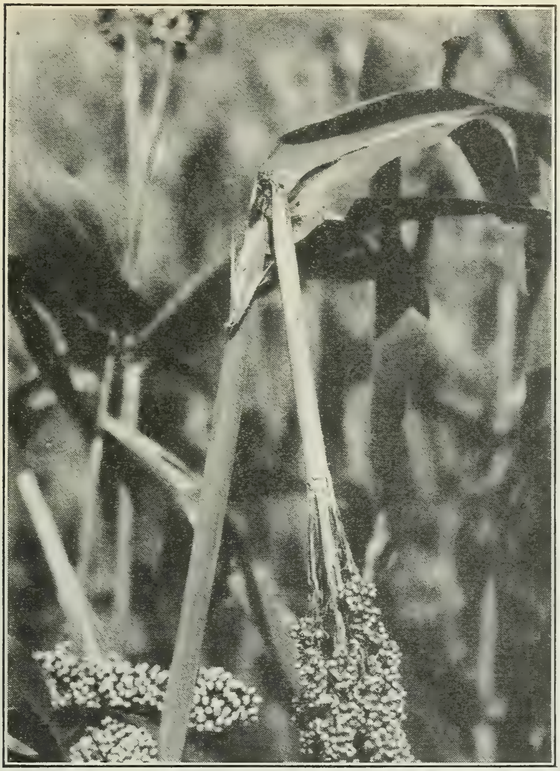

FIG. 33.—Typical injury to hegari by European corn borer. Woburn, Mass., September 29, 1921

TABLE 20.—*Percentage of weeds infested by Pyrausta nubilalis larvae (New England, 1920–21)*

Plant name	Number fields or waste areas	Total number plants examined	Total number found tunneled	Total number containing larvae	Per cent plants containing larvae	Total number larvae found	Average number larvae per 100 plants	Maximum number larvae per plant
Xanthium spp	4	170	168	162	95.3	1,067	627.6	35
Chenopodium ambrosioides	3	70	63	50	71.4	95	135.7	7
Polygonum spp	11	411	228	198	48.1	701	170.6	27
Ambrosia artemisiaefolia	6	205	(1)	91	44.3	135	65.8	6
Echinochloa crus-galli [2]	5	325	153	136	41.8	175	53.8	2
Artemisia biennis	3	115	48	41	35.6	91	79.1	6
Arctium minus	5	115	81	40	34.8	123	106.9	17
Bidens frondosa	4	130	66	45	34.6	77	59.2	5
Iva xanthifolia	1	50	32	17	34.0	26	52.0	4
Rumex spp	4	260	88	84	32.3	129	49.6	3
Erechtites hieracifolia	2	35	13	9	25.7	9	25.7	1
Amaranthus retroflexus	10	636	189	135	21.2	172	27.0	7
Lactuca scariola var. integrata	1	50	11	9	18.0	17	34.0	3
Erigeron canadensis	2	80	5	5	6.3	7	8.8	2
Chenopodium album	2	100	6	6	6.0	6	6.0	1
Tanacetum vulgare [2]	2	75	8	4	5.3	6	8.0	3
Galinsoga sp	1	200	10	3	1.5	3	1.5	1

[1] Not possible to discriminate between tunnels of *P. nubilalis* and those of other borers present in same plant.

[2] Each stem counted as a separate plant.

During the early spring some of the larger and more substantial weeds, such as Xanthium, Arctium, and Polygonum, frequently contain a greater number of larvae per plant than is shown in Table 20. Many of the larvae contained in large weeds at this time have migrated during the late autumn from more fragile weeds such as Echinochloa, or from the remnants of near-by cultivated plants. During the spring of 1922 a total of 203 larvae were taken from a single plant of Xanthium and 75 larvae from a single stalk of Polygonum.

The prevalence of the borer in weed growths has increased in intensity, especially since the abandonment of large-scale burning and weed-control operations. This increased infestation may be partly due to the reduced acreage planted to corn in the badly infested districts, but in any event during the late summer of 1922 a series of detailed field counts showed that in three large typical weed areas (fig. 34) located at Cambridge, Watertown, and Arlington, Mass., and aggregating 85.3 acres in size, there were from 277,000 to 406,000 borers per acre. The predominating weeds in these areas were barnyard grass, pigweed, lamb's-quarters, cocklebur, beggar-ticks, bread grass, and Mexican tea. These neglected weed areas act as sources of infestation to the surrounding territory for many miles through the flight of the adults, and locally by the migration of larvae.

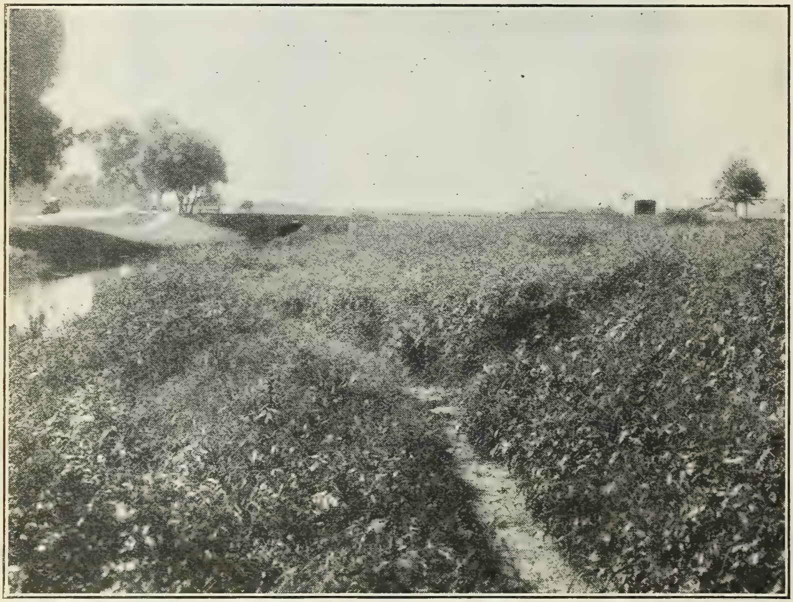

FIG. 34.—Typical weed area in New England, severely infested by European corn borer. Similar weed areas contained over 400,000 borers per acre

DESCRIPTION

THE EGG

Average length 0.97 millimeters, average width 0.74 millimeters; elliptico-ovate, sometimes nearly circular in contour, thin, more or less scalelike, slightly convex on its uppermost surface, flat on its undermost surface or conforming with the surface of the object upon which the egg is deposited. Chorion reticulated with fine elevated lines, which anastomose regularly and thereby inclose shallow pentagonal or polygonal foveae. Eggs when first laid greenish white, more or less translucent on the periphery, the opacity increasing centrally where the egg attains its greatest depth; ordinarily strongly iridescent. In 18 to 24 hours after deposition there appears in the egg a crecentiform clear area, slightly excentric in its position as viewed from above; the balance of the egg becoming strongly opaque. Two days before hatching the egg assumes a yellowish cast, and soon thereafter the head capsule of the inclosed larva is seen, its chitinization proceeding rapidly. Several hours before hatching the chorion collapses about the larva and its shape is plainly evident. At time of hatching the head and thoracic shield are black; the body segments are yellowish white.

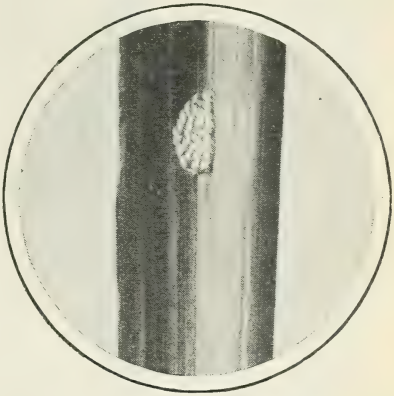

FIG. 35.—Egg mass of the European corn borer. Greatly enlarged

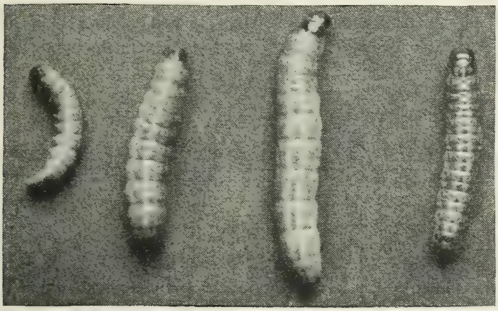

FIG. 36.—Larvae of the European corn borer. Slightly enlarged

The eggs commonly are deposited in irregularly shaped masses (fig. 35), and less frequently in regular rows. The mass is flat and easily removable from the object upon which it is laid. The eggs in the mass are overlapped, shingle-like, with successive eggs deposited by the female. According to records obtained, they range from 1 to 162 in number, 15 to 20 eggs representing the average size of the mass.

THE LARVA

Full-grown larva (fig. 36), average length 20 to 23 millimeters, width 3 to 3.5 millimeters. Body cylindrical, abdominal segments, except 9 and 10, grooved transversely. Body dirty white, shading from light brown, or dark brown, to pink on the dorsum. Dorsum heavily granulated, skin granulations extending to the pleurae, heavily granulose along dorso-median line, taking the form of a band or stripe. Chitinized areas of the body heavily pigmented, especially about the tubercles; thoracic shield yellowish brown, bordered or emarginated and more or less spotted with dark brown; anal shield yellowish; irregularly spotted with grayish brown. Chitinized areas of tubercles quite large, oval, and circular, yellowish and emargined with brown. Thoracic legs yellowish, claws brown; crochets on planta of prolegs triordinal. Spiracles ovate.

Head polished brown to black, sometimes more or less blotched; mandibles strong, five-toothed, more or less square, distal tooth pointed. "Anterior setæ A^1 and A^2 and puncture A^a in a line or with A^a a trifle postero-laterad of A^2, not postero-dorsad; A^2 somewhat nearer to A^1 than to A^3, A^1, A^2, and A^3 forming a decided obtuse angle" (*24, p. 174*).

The majority of the larvae in the field have five instars. In the rearing experiments shown in Tables 24 to 27 the majority of the larvae had four instars, a considerable number had five instars, and a few larvae had six instars; and in one series a few individuals had seven instars.

FIRST INSTAR

Prothoracic shield averaging 0.25 millimeter. A perceptible indentation present, but no division of the shield along medio-dorsal line. Indentation at cephalo-medio dorsal point.

SECOND INSTAR

Prothoracic shield averaging 0.41 millimeter in width. Indentation along dorso-median line increased but shield not divided.

THIRD INSTAR

Prothoracic shield averaging 0.71 millimeter in width. Division or indentation extended to half way between cephalic and caudal margins along dorso-median line.

FOURTH INSTAR

Prothoracic shield averaging 0.98 millimeter in width. Division of shield complete. Color of prothoracic shield black.

FIFTH INSTAR

Prothoracic shield averaging 1.72 millimeters in width, light yellow maculated with darker, smoky-fuscous areas. Larval body usually more robust than preceding.

THE PUPA

Average length of male pupa, 13 to 14 millimeters; female, 16 to 17 millimeters. Average width of male, 2 to 2.5 millimeters; female, 3.5 to 4 millimeters. (Fig. 37.)

Color yellowish brown; cephalic and caudal extremities brown to black; cremaster nearly black; dorsum of thorax darker than general body color, but not shining.

Moderately slender; abdominal segments tapering caudad; sterna smooth; terga of abdominal segments with transverse wrinkles and two rows of spines on segments 1–7; appendages compacted against the body. Wings, maxillae, and mesothoracic and metathoracic legs approximately equal in length, extending to the mesal part of the fourth abdominal segment ventrad; metathoracic legs lying directly beneath the mesothoracic; prothoracic legs terminating half way between the head and the tips of the wings; prothoracic femora plainly indicated; antennae terminating short of the wings. Labrum and pilifers well developed; labial palpi small. Proleg scars visible on the sterna of abdominal segments 5 and 6; a pair on each segment. Dorsum of the thorax bearing a slightly elevated ridge extending along the dorso-median line; thorax only slightly humped. Abdominal spiracles small, oval, slightly produced, rings stoutly chitinized, blackish brown. Caudal segment terminating in a dark-brown or black cremaster, prominent, spatulate, stout, longer than broad, and armed at its extremity with a series of 5 to 8 recurved spines, which serve to fasten the pupa to its cocoon or to a pad of silk spun by the larva prior to pupation. The pupa ordinarily, but not always, is enveloped in a very thin cocoon. The anal and genital openings are slitlike in both sexes.

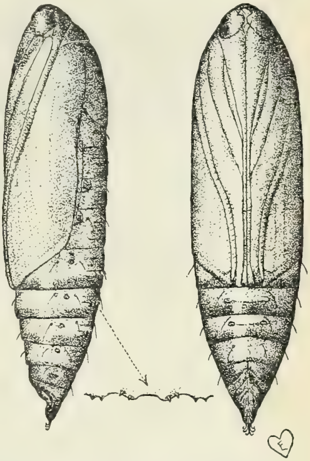

Fig. 37.—Pupa of the European corn borer, lateral and ventral views. About three times natural size

The sexes are readily separated by comparing the position of the genital opening with the seventh abdominal spiracles, which are constant or fixed in their position. In the female the genital opening is cephalad of the seventh abdominal spiracles, whereas in the male the genital opening is cauded thereto.

ADULTS

(Fig. 38)

MALE

Alar expanse 20 to 26 millimeters; length of body in both sexes 13 to 14 millimeters.

Head and thorax cinnamon brown on the thorax; white ventrad. Labial palpi porrect, snow white ventrad, otherwise grayish fuscous. Maxillary palpi erect, slightly dilated at apex. Proboscis long, covered with cream-colored scales, tightly coiled and almost hidden when viewed laterad. Antennae filiform in both sexes, terminal half curled in dried specimens, two-thirds the length of the cephalic wings.

Prothoracic legs snow white outwardly, slightly fuscous inwardly; mesothoracic and metathoracic legs white. Inner spurs on legs twice the size of the outer ones. Cephalic and caudal wings equal in width, costal margin gently curved toward the apex, anal angle rounded, inner margin straight. Cephalic wings reddish brown or grayish fuscous, with a bright ochreous discal spot and a like colored serrate band running the width of the outer third of the wing. This band is frequently cut into by extensions of the grayish fuscous coloration present on the outer third of the wing, so that at times the band tends to be broken up into series of lunate spots. Hind wings dark grayish fuscous, with a broad median fascia which does not attain the cephalic or caudal margins of the wing. Male specimens reared at high temperatures are brilliant, the cephalic wings possessing a pleasing blue-gray hue. Likewise females reared at high incubator temperatures are highly colored and deviate to a large extent from the type specimen in the field. Abdomen dark grayish fuscous above, white beneath; caudal margin of segments on the dorsum with a fine line of white scales. Frenulum consisting of one long stout spine.

Genitalia strongly chitinized; anellus with two dorsal projecting lobes supported by two chitinous arms; face of clasper oval and spinose; tegumen trifurcate; sacculus of the harpe bearing one large and two smaller stout spines.

FEMALE

Alar expanse 25 to 34 millimeters.

Cephalic wing of the female dull yellow or sometimes sulphurous, the costa and inner two-thirds of the wing more or less streaked with brown; a serrate brown line is present on the outer third of the wing and extending its width, followed on the outside by a narrow yellow band more or less serrate on its outer margin. On the outside of the latter there is present a brown band interspersed with yellow. Caudal wing grayish brown with a rather broad light ochreous fascia beginning slightly caudad of the costa and terminating short of the caudal margin of the wing. In some specimens cephalic wings may be dull yellow and cinnamon brown tinged with ferruginous, and with the caudal wings very pale brown streaked irregularly with shades of darker color. Frenulum of the female consisting of two long spines and a shorter, more slender one.

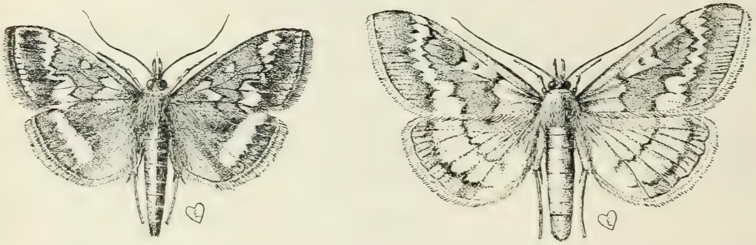

FIG. 38.—Adults of the European corn borer: At left, male moth; at right, female moth. Not quite twice natural size

Ovipositor terminating in a chitinous plate emargined with long and shorter amber-colored setae; genital opening without strongly chitinized cephalic margin; chitinized plate caudad of the genital opening well developed.

SEASONAL HISTORY

The seasonal history of the corn borer in various localities is variable, as would naturally be expected of any widely dispersed insect; but a somewhat surprising feature is that in localities where the climatic complex is superficially the same, there is a variation in the number of generations annually. Between the areas of infestation in eastern Massachusetts and western New York, the early spring mean temperatures, the frost dates in spring and fall, and the length of the growing season are comparable. If there is any apparent difference in the two localities it is slightly cooler in eastern Massachusetts than in the western New York area of infestation, yet in eastern Massachusetts there are normally two generations a year, or at least a preponderance of individuals which develop a second generation, whereas in western as well as in eastern New York but one generation occurs, judging from the observed behavior of the insect.

Table 21 gives a partial list of the localities where *Pyrausta nubilalis* is known to occur, with the corresponding number of generations annually. The data concerning the number of generations in the various localities have been taken from miscellaneous sources of information and, of course, represent only generalized conditions owing to the fact that in many of the foreign localities the field records of seasonal history, occurrence, and behavior are in many cases insufficient, and possibly inaccurate.

TABLE 21.—*Number of generations (annually) of Pyrausta nubilalis in various localities from which data are available*

Locality	Number of generations	Remarks
New England	2	1920,[1] 1 complete and 70 per cent of a second generation; 1921, 2 complete and a small partial third; 1922, 1 complete and 86 per cent of a second generation; 1923, 1 complete and 60 per cent of a second generation; 1924, 1 complete and 78 per cent of a second generation.
Eastern New York	1	One complete and a small partial second generation in 1921.
Western New York	1	Do.
Pennsylvania	1	Do.
Ohio	1	Do.
Michigan	1	Do.
Ontario, Canada	1	Do.
Southern France	2	
Northern France	1	
Southwestern Russia	1	Probably a partial second generation during favorable seasons.
Transcaucasia	2	
Belgium	1	
Netherlands	1	
Hungary	1	
Italy	2	A third generation is reported from environs of Florence.

[1] Two complete generations and a small partial third generation were reared in the insectary during 1918, and two complete generations were reared under the same conditions in 1919, but extensive field studies to determine generation development were not initiated until 1920.

SEASONAL DEVELOPMENT

Since the corn borer appears to be more destructive and presents a more difficult problem in localities having two generations in this country than in those having one generation, obviously it is a matter of economic importance to ascertain, if possible, the factors that determine the number of generations in localities within its present distribution. This information is necessary in order that the probable seasonal history of the insect may be forecast for various sections of the United States, should the insect become widely distributed. The solution of this problem has been approached from various angles.

The possibility that distinct biological species inhabit the New York and Massachusetts areas, which are one and two generation localities, respectively: The results have shown that individuals taken from both areas, as well as individuals from various foreign localities, crossbreed and are capable of producing fertile eggs. The project of rearing these hybrids is still under way.

The possible presence of geographic races: The manner of conducting experiments to determine this point was the transfer of material from one locality to the other, that is, from a one-generation locality to a two-generation locality, and vice versa, subsequently breeding the offspring for several years to observe their reactions to change in environment.

During the winter of 1920–21 a series of overwintering larvae were transferred from western New York to the Massachusetts area, and the progeny of this material have been carried through their entire seasonal development since that time in large field cages. A similar cage was used as a check in which native Massachusetts material has been reared under similar conditions, and the results from each lot of material checked by insectary rearings. The results during the first four years are shown in Table 22.

TABLE 22.—*Results of rearing Pyrausta nubilalis material transferred from western New York to Massachusetts during winter of 1920–21*

Source of material	Number of generations in original locality	Number of generations in Massachusetts			
		1921	1922	1923	1924
Silver Creek, N. Y. (environs)	1	1	1	1	1
Medford, Mass. (check)	2	2	2	(1)	[2] 2

---

[1] 1 complete, 2 partial.

[2] A second flight of moths was observed in this cage in 1924, but no dissections were made to determine the percentage of the second generation which developed.

Similar rearings were carried on at Silver Creek, N. Y., during the period 1921 to 1924 with two-generation material transferred from Massachusetts in the early spring of 1921. Under these conditions the Massachusetts material adhered to its two-generation seasonal development for this four-year period.

These experiments must be continued for a period of several years before any conclusions can be reached as to the effect that climatic factors may have in changing the number of generations through which the insect may pass in completing its seasonal development. The time of year when the material is transferred, and the method of handling after its arrival, as well as conditions under which the experiment is conducted, undoubtedly exert an influence during at least the first year or two of the experiment.

Climatic conditions: In the past, temperature, since it is conceded to be one of the most important stimuli for biological development, has been given great weight in the solution of many parallel problems.

A detailed study of the variation of climatic factors upon the seasonal history of this insect includes a course of experiments covering the study of the effects of the important climatic factors. The study of temperature consists of temperature work, carried on in incubators, where a constant temperature of great accuracy can be maintained, with the humidity conditions fairly uniform. The results of these experiments, in connection with important information obtained from the study of the behavior of the insect under field and insectary conditions, will be used when the data obtained are sufficient to warrant doing so, in an attempt to evaluate the temperature influence upon seasonal development. As is noted further on in the discussion, the other factors are being carefully studied, but until experimental proof becomes stronger, it would be unwise to draw definite conclusions from the available data regarding the future behavior of the insect under widely different climatic conditions.

In nearly all investigations of important economic pests the necessity has arisen of attempting correlations with one or more climatic factors to aid in forecasting the time of appearance and duration of important phenological events. The most common correlation to be found is that involving the effects of accumulated degrees of temperature, above a threshold of development, with the seasonal-history features. It has been determined by experimentation that the methods of correlation commonly used to express the temperature effects upon development are not satisfactory for practical purposes, and until a more basic knowledge is obtained concerning the reactions of the insect to its environment, the usual temperature summations will be avoided.

All the climatic factors, not temperature alone, must be studied to obtain the solution of these physiological problems.

Experimental work carried on at Arlington, Mass., to date has revealed the following points:

1. Moisture conditions, i. e., precipitation, humidity, and evaporation, have an apparent effect upon development, and in the case of humidity and precipitation, an effect that can not safely be averaged out.

1. Individuals in New England which experienced the usual winter temperatures but were deprived of moisture up until time for normal spring pupation in the field were delayed in their seasonal occurrence beyond the normal time, and as a result of this treatment only 60 per cent of the progeny produced the normal two generations.

2. Individuals which experienced a mean temperature of approximately 75° F. and an average humidity of less than 45 per cent during the hibernation period failed to pupate and died in large numbers. A small percentage completed development under these conditions. Individuals having a similar history, placed under field conditions at the time for normal pupation in the field, were greatly delayed in their development, and the progeny completed their development—60 per cent one generation, and 40 per cent two generations.

3. Preliminary correlation work shows that humidity deficiency raises the threshold of development and decreases the point of maximum rate of development.

2. Temperature (humidity conditions approximately 75 to 85 per cent):

	Egg	Larva	Pupa
	° *F.*	° *F.*	° *F.*
1. The reciprocal of the curve of development is not a straight line, except within certain limits, which are	67–87.5	61–81	62.5–87
2. The maximum rate of development occurs at	92	94.5	92
3. The optimum for development (fastest rate with least mortality) is	70–75	70–75	82–86
4. Straight-line threshold, as used by other workers, is	58.7	49.7	55.4
5. Actual threshold of development is	44.3	36.5	41.2
6. Corrections must be made for the different velocities of development which exist outside of the straight-line limits.			
7. The points as here given will vary in accordance with the humidity fluctuations or change in any of the other climatic factors.			

The data given are only preliminary, since all of the experimental results have not as yet been carefully checked.

Although in the past the effect of humidity upon the development of an insect whose life habits prevent it from directly experiencing continued atmospheric humidity, has been somewhat discounted, it has been found that, in some manner, humidity does play an important rôle in the development of the corn borer. How the external humidity affects the borer within the stalk can, of course, only be conjectured; but the fact that it does affect it serves to illustrate the fallacy of attempting to derive a close correlation between development and a single factor of climate, which will apply and prove useful over a period of years.

In the investigations thus far the importance of fluctuation of temperature in lengthening or shortening a stage has been very marked, and in many instances where the temperature has been higher, humidity conditions the same, but fluctuation less, there has been a marked increase in the period required to complete a given stage.

The entire difference in duration of stages apparently produced by fluctuation is not due to the mere rise and fall of temperature. A study of recent constant temperature experiments shows that the lower temperatures, i. e., 10° or 15° above the actual threshold of development, have a much greater effect upon development than those temperatures 20° or 30° higher. Since during the spring months the daily temperatures are for a greater part of the time within these more influential limits, an accurate evaluation of the effects of these temperatures must be considered before any definite knowledge can be obtained concerning the possibilities of development at this time of year.

However, variation in temperature is more advantageous to development than is constant temperature, although the advantage seldom rises over 10 per cent in favor of the former, and in most cases can be figured at 2 or 3 per cent.

The results of the experiments in connection with this type of investigation will be advanced far enough in the near future to warrant a more detailed discussion of these physiological reactions. Although it is not expected that a definite mathematical interpretation can be evolved that will express the effects of climate in relation to development, it is hoped that certain definite facts may be learned which will give a much clearer appreciation of the possible reactions of the insect to its environment.

Precipitation, as a determinant of development in entomological research, has not, until very recently, been given the attention which, upon closer scrutiny, it seems to merit. That the distribution of precipitation during the winter and spring months is of immense importance biologically can not be denied, but in just what particular manner this factor affects the future seasonal activities of this insect can not at present be explained.

During the last three years a preponderance of precipitation in March, April, and May, followed by a dry June, induced an early start of the insect in New England, and so far under these conditions a complete second generation has occurred and evidences of a partial third generation were observed. On the other hand a deficiency of rain in March, April, and May, followed by a rainy

June, were unfavorable, and in those years in which such conditions have prevailed there has been a diminution in the number of individuals developing a second generation.

In order to present a picture of conditions in several representative localities where *P. nubilalis* is known to exist, a series of climographs for these localities have been constructed, following the methods of Taylor (*66*) and Shelford (*57*). These are shown in Figures 39 and 40. All data used in the construction of these climographs have been based upon normal means, and the graphs may be taken as representing mean conditions of typical localities in the areas indicated. Temperatures are plotted along the "Y" axis and tenths inches of precipitation along the "X" axis. The numerals along the lines composing the graphs refer to the months of the year. The 3-inch precipitation line has been made a heavy broken line to give an easier means of comparison and differentiation between the months. It must be understood that these graphs will not indicate definite conclusions; they serve rather to show the differences in climate existing in normal years. The comparative deficiency of precipitation which exists in the one-generation areas can be readily appreciated by a comparison of Figure 39, C and D, with Figure 39, B, which represents a two-generation area. In view of the uniform advantage of temperature which Hungary, represented by Figure 39, C, has over New England (fig. 40, A), the deficiency of precipitation in Hungary would lead one to believe that here was a potent factor in limiting the number of generations annually to one, whereas the New England climate (temperature and precipitation) has been favorable for two generations. Compare the localities in the United States known to be infested by *P. nubilalis*; New England (fig 40, A) with eastern and western New York (fig. 40, B and C) and Ohio (fig. 40, D). Note the difference in the distribution of precipitation, particularly during the winter and early spring. Again the deficiency and distribution of precipitation appear to separate New England's two-generation area from the New York and Ohio one-generation conditions.

The graphs for the Corn Belt (fig. 39, A) have been inserted as a means of visualizing the normal conditions which exist in the 10 towns selected in comparison with the localities from which seasonal history information has been obtained. Note the dotted graph of Sioux City. Again, the comparative deficiency of precipitation during the critical winter and early spring months would lead one to believe that there would be a strong possibility of only one generation in that section of the United States.

The accompanying graphs representing the one and two generation localities are typical of similar graphs constructed for 111 single-generation and 52 two-generation localities in Europe, Asia Minor, and the United States, where *P. nubilalis* exists and from which seasonal-history data are available. It must be borne in mind, however, that such comparisons are certainly not proof of what might happen in similar areas not now infested, although useful in studying locality conditions and in formulating various hyphotheses which must be tested experimentally. Prognostications founded upon empirical comparisons of this nature are extremely dangerous and should be used only as a key to avenues of experimentation.

Considering the inadequacy of the experiments here described definitely to establish the relation between climatic factors and the various phases of development, it would not be expedient to advance at this time a conclusive statement regarding the status of the insect in new localities to which it may spread.

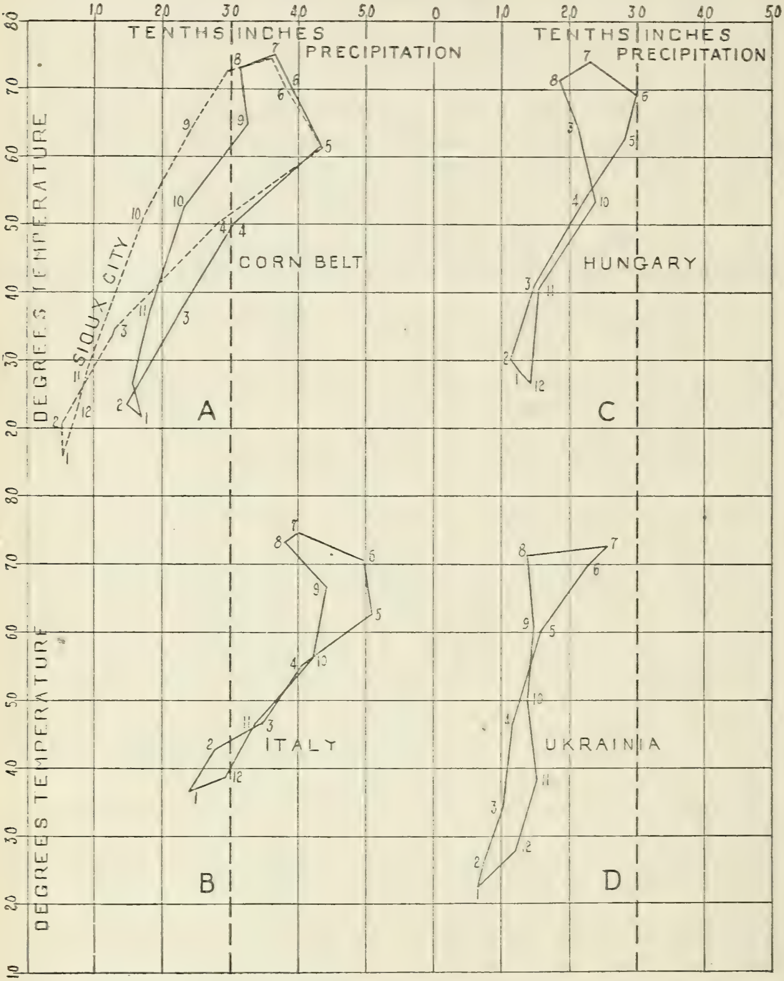

FIG. 39.—Climographs of typical localities in the Corn Belt, and of localities known to be infested in Italy, Hungary, and Ukrainia. Constructed from the averaged normal means (Weather Bureau) of the towns listed under each locality

A, Corn Belt: Sioux City, Iowa; Clarinda, Iowa; Webster City, Iowa; Waterloo, Iowa; Mount Pleasant, Iowa; Monmouth, Ill.; Pontiac, Ill.; Urbana, Ill.; La Fayette, Ind.; Bluffton, Ind.

B, Italy (two generations): Treviso, Oderzo, Conegliano.

C, Hungary (one generation): Bacsfoldvar (Yugoslavia), Hodmezo-Vasarhely, Mesohegyes.

D, Ukrainia (one generation): Poltava, Odessa, Nikolaev, Kherson.

K. W. Babcock began in 1924 a careful survey of the insect in its native home, with a view to obtaining accurate data concerning the reactions of the insect to its environment in localities where there has been a good chance for a long period of adaptation. These data should give an accurate means not only of defining the best methods of studying the insect experimentally but also should serve as a basis for more accurate knowledge concerning the possibilities of damage under particular environmental conditions.

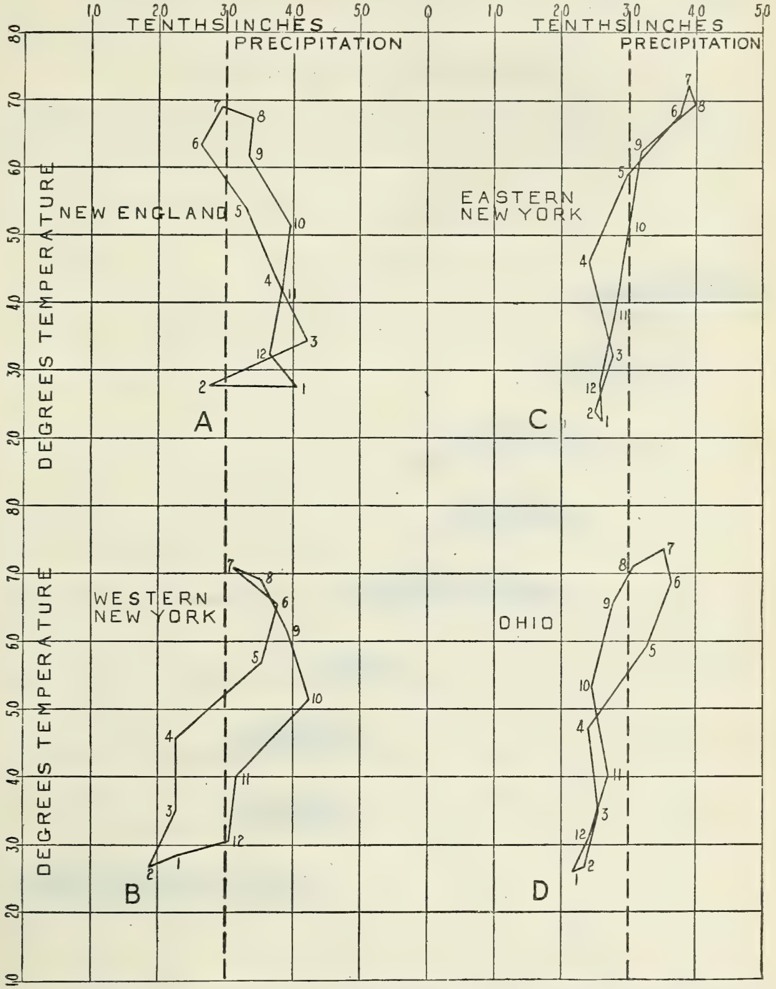

FIG. 40.—Climographs of typical localities infested in New England, western New York, eastern New York, and Ohio. Constructed from the averaged normal means (Weather Bureau) of the towns listed under each locality

A, New England (two generations) : Boston, Mass. ; Rockport, Mass. ; Plymouth, Mass. ; Provincetown, Mass.
B, Western New York (one generation) : Buffalo, Fredonia.
C, Eastern New York (one generation) : Albany.
D, Ohio (one generation) : Cleveland, Toledo, Sandusky.

SEASONAL OCCURRENCE

A knowledge of the date of appearance, the maximum occurrence. and last records of the different stages of any insect is indispensable and often of great practical importance in the application of control practices as well as in the selection of proper quarantine dates.

EASTERN NEW ENGLAND AREA

In order to present a general idea of the seasonal occurrence of *Pyrausta nubilalis* in New England, a graph has been constructed (fig. 41) based upon the average obtained from actual observations in the field and from insectary rearings during the five-year period from 1918 to 1922, inclusive.

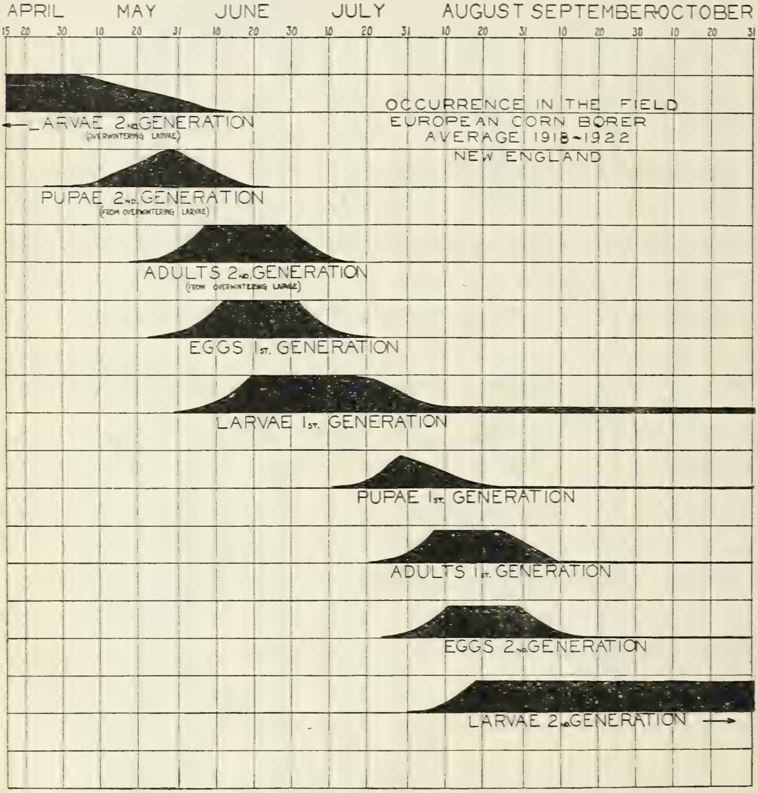

FIG. 41.—Seasonal occurrence of the European corn borer in New England. Averaged from data obtained during the period 1918 to 1922, inclusive

Prior to 1922 no systematic field examinations were made with this particular object in view, consequently it was necessary in the instance of some of the stages, notably the first occurrence of eggs and larvae in certain years of the five-year period, to depend upon insectary records, or to compute the first occurrence from the known presence and duration of the preceding stage in the field. This procedure undoubtedly affected to a slight extent the computation of the five-year average shown in Figure 41, consequently the average date of the actual presence of eggs and larvae in the field during this period may have occurred a few days earlier or later than is indicated. Since, however, the majority of these records were based upon averages of actual field observations, it is believed that the seasonal occurrence of the stages as shown in Figure 41 represent closely the average occurrence during this five-year period. A detailed explanation of the manner in which this chart and the three following charts were constructed is given in another publication (*7*).

During the season of 1922, beginning March 23 and extending to September 8, a systematic investigation was conducted to determine more accurately the occurrence of *P. nubilalis* in the field. Field examinations were made to ascertain the occurrence and progress of pupation and adult emergence in representative localities in the Massachusetts area, on practically every working day throughout the season when weather conditions permitted. The examinations occurred in corn and Xanthium, although some of the more widely distributed and susceptible weeds, such as Echinochloa, Bidens, Amaranthus, and Polygonum, were included. During the course of the season 559 separate examinations were made, involving a total of 71,528 individuals.

With the information concerning the occurrence and progress of pupation and adult emergence at hand, similar data relating to eggs and larvae were computed from the known duration of the adult stages and incubation period, as determined by contemporaneous insectary rearings, supplemented by observations in the field. The daily percentages of larvae, pupation, and adult emergence which were found at the time of examination, averaged for all localities and food plants, are shown graphically in Figure 42. The incidence of eggs and younger larvae, as well as the larvae entering hibernation, is indicated by dotted lines. The prevalence of first-generation larvae which hibernated in that stage, consisting of about 1.4 per cent of the total larvae present, is shown by a dotted extension.

The fact should be emphasized that the percentage of each stage designated in Figure 42 as being present in the field on a given date is an average for all localities and food plants. In general the incidence of egg deposition as well as the development of the larvae and subsequent pupation in the summer broods was earlier in the early corn than in the later corn. For this reason the percentage of larvae, pupae, and empty pupal cases (denoting adult emergence) often varied considerably on the same date in different corn plantings in the same field or farm, during the growing season. Since 1922 was in most respects a normal season it is believed that the progress of seasonal development during that season as represented in Figure 42 was very nearly typical, although it is realized that this procedure must be repeated for several years before definite, reliable information on this point can be secured.

For the purpose of illustrating more graphically the occurrence of each stage of *P. nubilalis* in the field during 1922, a graph (fig. 43) has been constructed based upon the field examinations discussed above. The black areas represent the actual field counts, while the areas inclosed by dotted lines are computed from the occurrence and the known duration of the preceding stages, as determined by contemporaneous insectary rearings, supplemented by observations in the field.

NEW YORK AREAS

The seasonal occurrence of each stage of the corn borer is usually from three to four weeks later in the New York areas than in New England.

Figure 44 represents graphically a general idea of the seasonal occurrence of *P. nubilalis* in New York during the period from 1920 to 1922, based upon the averages obtained from actual field observations in the environs of Scotia and Silver Creek, as well as from contemporaneous insectary rearings. Owing to the sparse infestation and the consequent difficulty in making field examinations during the early season, it is believed that the records pertaining to the beginning of pupation, adult emergence, and egg deposition are a few days later than the actual appearance of these stages in the field.

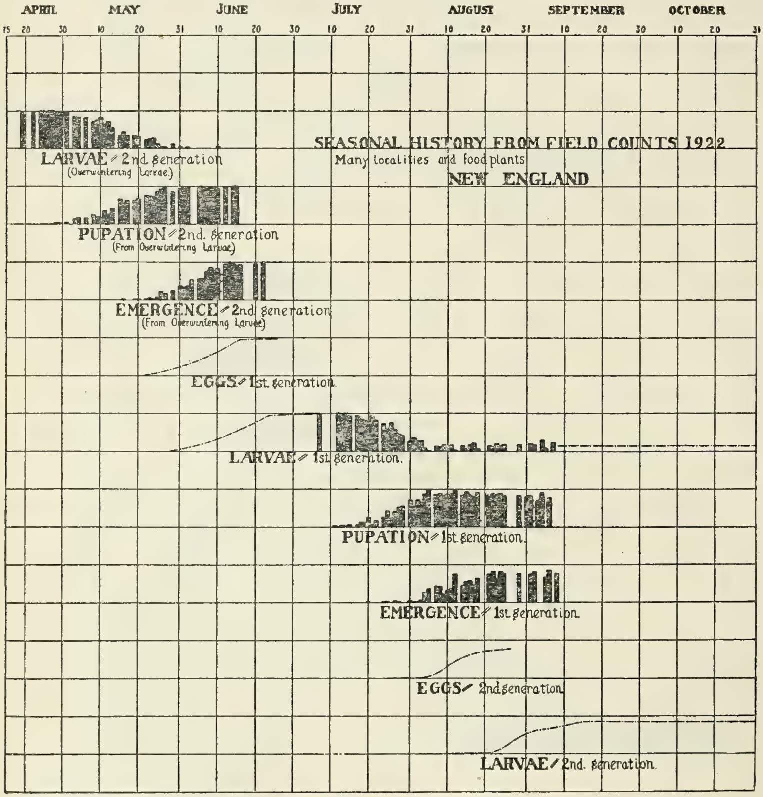

FIG. 42.—Seasonal history of the European corn borer in New England during 1922. Black areas denote per cent of each stage in the field, as determined by field counts. Dotted lines show the probable occurrence (in per cent) of eggs and young larvae, as determined by plotting rearing records. Dotted line following the graph of first-generation larvae indicates the per cent of single-generation individuals

The records for 1920 were obtained principally from Scotia, and for 1922 from Silver Creek, whereas during 1921 complete records were obtained from both localities. During 1921 the seasonal occurrence of each stage of the corn borer at Scotia coincided very closely with the occurrence of the same stage at Silver Creek.

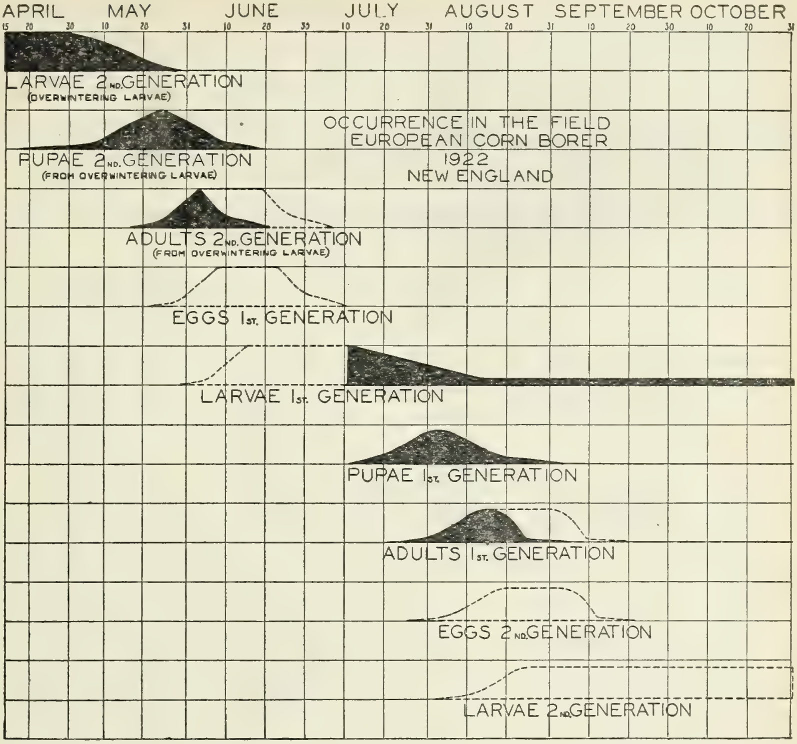

FIG. 43.—Seasonal history in New England during 1922. Black areas denote actual field counts. Areas inclosed by dotted lines show the probable occurrence of eggs and immature larvae, and the length of life of adults, as determined by plotting rearing records and from field observations

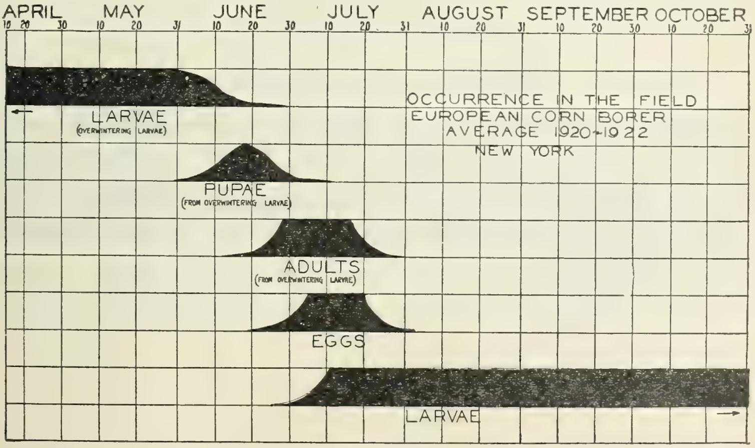

FIG. 44.—Seasonal occurrence of European corn borer in the infested areas of New York. Averaged from data obtained during the period 1920 to 1922, inclusive

OHIO

Owing to the comparatively sparse infestation existing in Ohio, it has not been possible to conduct extensive or detailed field studies to determine dates of seasonal occurrence. During 1923 and 1924, however, some preliminary data were accumulated upon this point by F. W. Poos and L. H. Patch, a summary of which appears in Table 23, showing the seasonal occurrence of each stage. Most of these observations were made in the vicinity of Sandusky, Ohio.

TABLE 23.—*Summary of seasonal-occurrence notes on the European corn borer at Sandusky, Ohio, for 1923 and 1924*

Stage	Date of first record				Date of greatest abundance (approximate)			
	1923		1924		1923		1924	
	Laboratory	Field	Laboratory	Field	Laboratory	Field	Laboratory	Field
Pupa	June 15		June 20	June 23	June 28		July 10	
Adult	June 26		July 1	July 2	July 16		July 25	
Egg	July 2	July 10	July 5	July 9	July 18			
Larva	July 9	July 11		July 11		Aug. 5–10		Aug. 20

Stage	Date of last observed record			
	1923		1924	
	Laboratory	Field	Laboratory	Field
Pupa	July 2		Aug. 12	
Adult	Aug. 8		Sept. 2	
Egg	July 31			Aug. 3
Larva		(1)		(1)

[1] Overwintered

LIFE HISTORY

EASTERN NEW ENGLAND

The seasonal occurrence of each stage of the corn borer in eastern New England for the period 1918 to 1922 has been given in Figures 41, 42, and 43. The average duration of the stages of *Pyrausta nubilalis* in eastern New England, as obtained from insectary records at Arlington, Mass., during the period from 1919 to 1921, inclusive, are shown in Table 24.

TABLE 24.—*Duration of stages of Pyrausta nubilalis in New England (Arlington, Mass.), 1919 to 1921, inclusive*

	1919				1920				1921			
	First generation		Second generation		First generation		Second generation		First generation		Second generation	
	Average in days	Number of specimens	Average in days	Number of specimens	Average in days	Number of specimens	Average in days	Number of specimens	Average in days	Number of specimens	Average in days	Number of specimens
Egg stage	7.14	2,990	7.84	6,087	7.16	4,600	6.25	4,992	7.00	4,053	7.31	20,727
Larval period:												
First instar	4.98	154	6.76	30	4.50	59	5.60	18	5.54	24	4.00	87
Second instar	4.70	152	5.44	30	4.70	59	5.90	18	5.40	24	5.20	87
Third instar	4.84	151	7.86	30	4.00	59	9.30	18	5.48	23	5.20	87
Fourth instar	7.50	147	8.83	[1]30	6.90	59	12.10	[1]18	4.18	22	6.49	87
Fifth instar	13.10	[1]113	15.30	7	13.80	[1]56	14.40	7	9.50	21	------	------
Sixth instar	12.70	40	25.00	2	12.20	5	16.00	1	------	------	------	------
Seventh instar	11.00	8	------	------	------	------	------	------	------	------	------	------
Total larval period [2]	35.12 to 58.82	---	[2]28.89 to 69.19	---	33.90 to 46.10	---	[2]32.90 to 63.30	----	30.10	------	[1]20.89	------
Pupal period:												
♀	10.94	197	18.76	103	11.04	91	19.14	28	9.86	61	18.12	114
♂	12.61	244	20.41	118	11.92	71	20.71	23	9.24	54	19.04	126
Adult stages:												
Preoviposition	4.30	109	5.10	120	3.20	93	4.10	17	2.60	42	4.60	21
Oviposition	11.80	109	14.10	120	9.50	93	10.60	17	13.00	42	6.80	21
Postoviposition	3.20	109	1.50	120	1.70	93	3.80	17	2.60	42	4.50	21
Longevity ♀	19.30	109	20.70	120	14.40	93	18.50	17	18.20	42	15.90	21
Longevity ♂	20.20	102	19.50	110	15.20	83	21.10	16	17.10	46	16.00	21
Total period from egg to egg	57.60 to 81.20	----	------	----	55.30 to 67.50	----	------	-----	49.56	-----	------	------

[1] The duration of the total larval period varied because a majority of individuals pupated (in the first generaton) at the end of the fourth or fifth instar, whereas other individuals had additional instars. Similarly, in the second generation the length of larval life to the last molt prior to entrance to period of winter inactivity varied because a majority of the larvae entered this period at the end of the fourth instar, whereas others developed fifth and sixth instars.

[2] To last molt in second generation; not including indefinite duration of last instar and winter period of inactivity.

From Table 24 it is seen that during the three-year period the average duration of the egg stage each year varied from 7 to 7.16 days for the first generation and from 6.25 to 7.84 days for the second generation. The average duration of the larval period each year, for the majority of the individuals under observation, varied from 30.1 to 35.12 days for the first generation and from 20.89 to 32.9 days for the second generation to the last molt. This does not include, of course, the indefinite duration of the last instar and its winter period of inactivity. Under insectary conditions four instars were developed by the majority of the individuals in both generations, although six and seven molts before pupation were recorded by a few individuals of the first generation, and a few of the reared larvae of the second generation recorded five and six molts before reaching full growth preceding the period of winter inactivity. The average duration of the pupal period each year varied from 9.86 to 11.04 days for the females, and from 9.24 to 12.61 days for the males of the first generation, and averaged from 18.12 to 19.14 days for the females, and from 19.04 to 20.71 days for the males of the second generation. The average duration of the preoviposition period each year varied from 2.6 to 4.3 days for the first generation, and from 4.1 to 5.1 days for the second generation. The average total life cycle of the first generation, from the egg to the termination of the preoviposition period of the female, varied each year from 49.56 to 57.6 days for the majority of the individuals under observation. The duration of the total life cycle of the second generation includes the winter period of inactivity and can not, therefore, be accurately expressed.

The duration of the egg stage was obtained by isolating individual egg clusters in small salve-box and plaster-of-Paris cages as soon as deposited by females in confinement.

The duration of the larval instars was determined by isolating newly hatched larvae in cages containing stems and leaves of corn and other favored food plants (Rumex and Amaranthus). After the larvae entered these plant portions it became necessary to make daily dissections in order to determine molts. This procedure resulted in a heavy mortality of the larvae under observation, and undoubtedly prolonged the duration of the instars of the surviving larvae. No satisfactory rearing cage or rearing method has yet been devised which will permit frequent examinations of *P. nubilalis* larvae for molts without disturbing the feeding larvae to such an extent as to affect their normal development. Therefore, for this reason alone, the average for the total period of larval development in each generation shown in Table 24 probably varies to a considerable extent from the actual duration of the larval period in the field, in the case of individuals exposed to comparable conditions of temperature, humidity, etc.

The duration of the pupal period was obtained by isolating full-grown larvae in individual glass-tube cases and noting the pupal formation and adult emergence.

The duration of the adult stages was determined by confining pairs of newly emerged adults in individual lantern-globe cages placed over flowerpots filled with soil and containing a branch of Rumex or Amaranthus inserted in a tube of water buried in the soil. In this type of cage the females deposited eggs freely upon the leaves of the plant, and in many instances upon the sides of the lantern globe, as well as upon the cheesecloth with which the top of the cage was covered. The soil in the flowerpots was kept moist, and small wads of cotton soaked with water were also placed in the cage, thus providing necessary moisture for the confined adults.

NEW YORK

Table 25 gives a rather incomplete record of the average duration of *P. nubilalis* stages at Silver Creek, N. Y., as obtained from insectary rearings during the period from 1922 to 1924, inclusive.

TABLE 25.—*Duration of stages of Pyrausta nubilalis at Silver Creek, N. Y.*

	1922		1923		1924	
	Average in days	Number of specimens	Average in days	Number of specimens	Average in days	Number of specimens
Incubation period			6.3	10,383	6.4	15,307
Larval period:						
First instar	6.18	64				
Second instar	3.76	64				
Third instar	5.16	63				
Fourth instar	[1] 13.47	58				
Fifth instar	16.92	13				
Sixth instar	12.00	1				
Total days to last molt [2]	[2] 28.6 to 57.5					
Pupal period:						
Female	13.34	29				
Male	14.00	26				
Adult stages:						
Preoviposition			9.5	39	5.8	42
Oviposition			12.5	39	11.3	42
Postoviposition			4.1	39	5.5	42
Longevity ♀			24.8	50	22.3	50
Longevity ♂			22.7	50	17.5	50

[1] A majority of the larvae entered the period of winter inactivity at the end of the fourth instar, but certain of them developed fifth and sixth instars.
[2] Not including indefinite duration of last instar.

In the 1923 and 1924 records pertaining to incubation and adult stages, shown in Table 25, 50 pairs of adults were used in separate cages. In the 1923 series 11 females and in the 1924 series 8 females did not deposit eggs. The averages for adult stages, except longevity, are based upon the number of females which deposited eggs.

TABLE 26.—*Duration of Pyrausta nubilalis stages at Scotia, N. Y.*

	1920		1921	
	Average in days	Number of specimens	Average in days	Number of specimens
Incubation	5.20	3,567	6.30	806
Larval period:				
First instar	9.00	15	4.39	97
Second instar	7.80	15	4.30	94
Third instar	6.00	15	4.61	86
Fourth instar	[1] 8.80	15	[1] 5.85	81
Fifth instar	8.50	6	8.50	38
Sixth instar	12.30	3	9.00	2
Total days to last molt [2]	[2] 31.6 to 52.4		[2] 27.7 to 35.7	
Pupal period:				
Female	12.22	40	11.80	30
Male	13.17	40	12.40	30
Adult stages:				
Preoviposition	6.90	122	7.90	30
Oviposition	11.80	122	11.40	30
Postoviposition	3.20	122	2.80	30
Longevity ♀	21.90	122	22.10	30
Longevity ♂	14.20	120	15.70	30

[2] Not including indefinite duration of last instar.
[1] See footnote 1, Table 25.

In the spring of 1921 a total of 100 overwintering larvae were caged at Silver Creek, N. Y., for pupation records. From this material a total of 14 females and 19 males were reared, the pupal period of the females averaging 10.93 days and for the males 11.26 days.

Table 26 gives the available records of the duration of life-history stages which were taken at Scotia, N. Y., during the seasons of 1920 and 1921.

OHIO

Table 27 gives a summary of the available records relative to the duration of life-history stages at Sandusky, Ohio, during 1923 and 1924.

TABLE 27.—*Duration of Pyrausta nubilalis stages at Sandusky, Ohio*

	1923		1924	
	Average in days	Number of specimens	Average in days	Number of specimens
Incubation period	5.04	4,801	5.58	17,693
Larval period:				
First instar			4.32	100
Second instar			4.56	100
Third instar			4.80	100
Fourth instar			[1] 7.94	100
Fifth instar			8.83	24
Total days to last molt [2]			[2] 21.6 to 30.5	
Pupal period:				
Female	12.41	39	12.12	16
Male	12.39	46	13.25	20
Adult stages:				
Preoviposition	2.79	24	3.68	47
Oviposition	6.46	24	14.85	47
Postoviposition	1.50	24	2.59	47
Longevity ♀	9.60	25	19.70	50
Longevity ♂	12.40	34	22.50	78

[1] See footnote 1, Table 25.
[2] Not including indefinite duration of last instar.

The records pertaining to incubation and adult stages which appear in Table 27 were obtained by confining 25 pairs of adults in the 1923 series and 50 pairs of adults in the 1924 series, together with extra males in some of the cages. In the 1923 series one female and in the 1924 series three females did not deposit eggs. The averages for adult stages, except longevity, are based upon the number of females which deposited eggs.

LARVAL HABITS

HATCHING

About a day before hatching takes place the black eye spots and reddish mandible tips of the developing larva become discernible through the semitransparent chorion of the egg. A few hours before hatching the head and thoracic shield become black and assume a central position in the egg. The body segmentation and the black spines on the body of the larva are also plainly discernible before hatching. At this time the developing larva is curled up inside the egg with its mandibles resting upon the next to the last abdominal segment. These mandibles soon begin to move laterally, and the larva straightens itself out in such a manner that the mandibles are brought into contact with the eggshell. A slit in this is soon made and the larva crawls forth. After hatching, the larva feeds to some extent upon the empty eggshell, but has not been observed to entirely devour it.

FERTILITY AND HATCHING

The greater proportion of eggs deposited in the field and in the insectary were found to be fertile. Table 28 gives data relating to the percentages of fertile eggs, as observed during the progress of life-history studies at Arlington, Mass. The percentages of fertile eggs which hatched, excluding parasitism, are also shown.

TABLE 28.—*Fertility and hatching of Pyrausta nubilalis eggs* (*New England*)

Generation	In insectary			In field		
	Eggs under observation	Fertile eggs	Fertile eggs hatching	Eggs under observation	Fertile eggs	Fertile eggs hatching
	Number	*Per cent*	*Per cent*	*Number*	*Per cent*	*Per cent*
First, 1919	13, 893	87. 2	--------	--------	--------	--------
Second, 1919	27, 285	94. 3	--------	2, 245	98. 1	98. 9
First, 1920	14, 886	89. 5	95. 7	--------	--------	--------
Second, 1920	19, 646	85. 7	96. 4	--------	--------	--------
First, 1921	4, 053	96. 1	--------	--------	--------	--------
Second, 1921	20, 727	97. 2	--------	--------	--------	--------
Second, 1923	--------	--------	--------	5, 232	94. 3	--------
Average	--------	91. 5	96. 0	--------	95. 4	98. 9

From Table 28 it may be noted that an average of 91.5 per cent of the eggs deposited in the insectary were fertile, and 95.4 per cent of the eggs observed in the field were fertile. An average of 96 per cent of the fertile eggs deposited in the insectary hatched, and 98.9 per cent of those hatched upon which observations were made in the field.

An average of 97.2 per cent of the eggs hatched under insectary conditions at Sandusky, Ohio, during 1923 and 1924. A total of 22,494 eggs were under observation in these experiments. At Silver Creek, N. Y., an average of 73.6 per cent of the eggs hatched under insectary conditions during this same period. A total of 25,690 eggs were under observation in this series. In a total of 11,320 eggs collected in the field in Ohio during 1924 an average of 99.3 per cent were fertile.

EFFECT OF DIRECT SUNLIGHT ON HATCHING

Direct sunlight appears to prevent the hatching of the eggs of *P. nubilalis*. During July, 1920, several leaves bearing clusters of fertile eggs were removed from life-history cages and inverted in such a manner as to expose the eggs to direct sunlight. Under these conditions none hatched. In the field the eggs usually are deposited upon the undersides of the leaves and are not directly exposed to the sun, although they have been found infrequently on the upper sides of the leaves and upon the stems of plants, as well as upon the husks of ears of corn.

EFFECT OF COVERING EGGS WITH SOIL

During the operation of cultivating small corn plants, some of the lower leaf blades bearing egg clusters often are covered lightly with soil. This treatment does not prevent the eggs from hatching, and, unless covered to a depth of at least 4 inches, most of the newly hatched larvae are able to make their way to the surface of the soil. In June and July, 1920, a total of 56 clusters of fertile eggs of the first generation were buried in damp sand-loam soil at depths varying from 1 to 4 inches. All of these eggs hatched. At a depth of 1 inch all of the resulting larvae came to the surface of the soil, at 2 inches 57 per cent, at 3 inches 57 per cent, while at a depth of 4 inches none of the larvae were able to reach the surface of the soil.

EFFECT OF TOTAL IMMERSION IN WATER ON HATCHING

During August, 1920, experiments were conducted to determine the effect of total immersion in fresh water upon the hatching of the eggs. The results of these experiments showed that fertile eggs did not hatch after a period exceeding 6.5 hours of total immersion. This fact may be of importance when treating plants or plant products bearing *P. nubilalis* egg clusters.

FEEDING HABITS OF LARVAE

The general feeding habits of *P. nubilalis* larvae have been previously discussed with relation to the character of injury to corn and to other plants.

METHOD OF FEEDING

The method of feeding by *P. nubilalis* larvae, as distinguished from their boring habits, is subject to a wide variation in accordance with the habits of individual larvae and with the stage of development of the plant, as well as with the part of the plant attacked.

When the eggs are deposited upon young corn plants of which the tassel has not yet appeared, the newly hatched larvae feed at first upon the upper and lower surfaces of the tender leaf blades, thus excavating small irregular-shaped areas in the epidermis. Some of the small larvae may also perforate the leaf blades surrounding the tassel, or work their way between the leaf blades and feed upon the developing tassel within. Once inside the tassel cavity, they feed upon and within the tassel buds. As the tassel expands and the larvae become larger, they enter the tassel stem or its branches and feed within. Instead of feeding upon and within the tender leaf blades and tassel, some of the newly hatched larvae habitually migrate to points lower down on the same or near-by plants, where they may enter the plant at practically any point, although their favorite place of entrance is between the leaf sheath and the stalk. Later in the development of the plant many of the larvae also enter between the stalk and the base of the ear, or they may enter the ear directly.

When the eggs are deposited upon corn plants which have reached the tassel stage, the newly hatched larvae usually do not attack the tassel, nor do they feed to any extent upon the surface of the leaf blades; under these circumstances they enter the stalk directly, or the thick midrib of the more tender leaf blades. If the plant has developed an ear, the newly hatched larvae frequently feed upon the tender tips of the husks and upon the silk, or work their way down between the silks into the ear and feed upon the grain and cob.

After the larva has entered the stalk it tunnels upward or downward. The character of the tunnel is subject to great variation, but typically the larva follows a nearly straight course through the pith and generally lengthwise of the plant. In some instances the tunnel is more or less winding and occasionally small cells are excavated along its course. Sometimes the larva also excavates a large horizontal chamber either just above or just below the entrance hole and starts its tunnel from this chamber. Stalks bearing this type of tunnel are greatly weakened and soon break over. All parts of the stalk may be tunneled down to and including the base or stubble. There is a tendency for the larvae to work in the internodes of the stalk, but many of the nodes are also perforated, especially where several larvae are present in the same stalk.

Even during the period of active growth of the larva it is apparent that not all of the plant substance removed by the larva during the process of tunneling within the stalk is actually devoured. The larva appears to prefer as food the portions of the interior of the stalk which are most succulent and rich in sugar. The harder and less nutritious portions of the stalk are merely bored out and cast aside. This discarded material, together with the excrement of the larva, is pushed out of the entrance hole in the form of yellowish-white frass, which later becomes darker in color. Much of this frass is held together in masses by silken threads spun by the larva and usually hangs suspended below the entrance hole or collects below in the axils of the leaf blades and upon the ground. Some of the frass, instead of being ejected from the tunnel, is packed by the larva into the cells or chambers of the tunnel.

When the larva bores an ear of corn it may enter directly at the tip, base, or side of the ear, or indirectly through the short stem by which the ear is attached to the stalk. Once inside the ear the larva tunnels through all parts of the grain and cob. The actual feeding areas on the grain may consist of long irregular surface furrows between the rows of kernels, or tunnels just underneath the upper surface of the kernels; or large irregular areas may be fed upon with no apparent regularity of procedure. The larvae tunnel the cob in a similar manner to that described for the stalk, the tunnels extending either longitudinally or transversely through the cob.

The feeding habits of the larvae when attacking plants other than corn are essentially the same as described for corn.

LARVAL ESTABLISHMENT AND SURVIVAL

In view of the known fecundity of the *P. nubilalis* female, as exhibited in confinement, and the number of eggs present in fields under close observation compared to the relatively small number of fully grown larvae which develop subsequently in such fields, it has been apparent that there must be a very high egg and larval mortality from natural causes, since the wide discrepancy between the number of eggs present and the number of fully grown larvae developing from such eggs could not, in most instances under observation, be accounted for by nonfertility, nonhatch, parasitism, disease, predators, or other assignable causes.

Cage experiments which were conducted at Sandusky, Ohio, during 1924 to obtain information upon the percentage of larval establishment and survival, and the causes contributing thereto, showed that an average of only 5.87 per cent of the eggs developed into larvae which became established in their host plant and survived to at least the third instar, in cases where such eggs were deposited upon growing corn plants (dent, flint, and sweet corn) by females temporarily confined in large cages while the eggs were being deposited. These cages were removed immediately after the deposition of the eggs to allow for the subsequent development of the insect and its host plant under natural conditions. Based upon the total larvae hatching in this series, an average of 8.36 per cent of the larvae became established in their host plant, as shown in Table 29, and reached at least the third instar before they were dissected from the plant.

TABLE 29.—*Summary of experiments of larval establishment and survival of the European corn borer at Sandusky, Ohio, 1924*

Type	Variety	Larvae under observation		Total larvae recovered		Per cent of recovery for type
		Date hatched (1924)	Number	Number	Per cent	
Flint	No data	July 17 to July 30	1,195	82	6.86	7.77
Do	do	Aug. 8 to Aug. 12	658	62	9.42	
Dent	Claridge	July 17 to Aug. 1	1,361	108	7.94	10.80
Do	Claridge, high per cent grain	Aug. 5 to Aug. 6	576	86	14.93	
Do	Claridge, low per cent grain	Aug. 5 to Aug. 7	784	100	12.76	
Sweet	Golden Bantam	July 17 to July 30	1,169	96	8.21	6.09
Do	Evergreen	July 17 to July 30	1,276	53	4.15	
	Total		7,019	587		
	Average					8.36

Of the total of 587 larvae shown as recovered in Table 29, definite records are available concerning the instars of 474 individuals in this group as follows: Thirteen larvae were in the third instar, 219 larvae in the fourth instar, 132 larvae in the fifth instar, and 110 larvae were mature. The remaining larvae recovered, 113 in number, had migrated to adjacent corn plants, and no records are available concerning the instars they represented. Close observation of the young larvae used in this experiment showed that the greatest mortality occurred during the first and second instars and was attributable to a variety of causes, the most important of which appeared to be desiccation, starvation, and drowning.

Complete records are not available pertaining to the number and percentage of eggs used in this experiment which failed to hatch or produce larvae. This information is available, however, for a portion of the eggs, 3,181 in number, and in this group 23.76 per cent were missed during their incubation period, presumably blown from the plants by the wind, 3.83 per cent failed to hatch, and 2.33 per cent dried up—a total egg mortality of 29.92 per cent. Assuming that the same rate of egg mortality was sustained by all the eggs used in this experiment, the total establishment and survival to at least the third instar, based upon the number of eggs in the experiment, equaled 5.87 per cent.

That the percentage of larval establishment and survival in the field is higher than that obtained in the experiment previously described is indicated by an analysis of 236 isolated infestations found in Ohio cornfields during 1924, wherein an average of 1.88 larvae were collected per infestation. Since each of 731 egg clusters collected in the field earlier in the season contained 15.5 eggs, on an average, the survival of 1.88 borers per infestation shows that 12.13 per cent of the eggs involved developed into larvae which became established, assuming that each of these isolated infestations developed from a single egg cluster.

VOLUME OF PLANT TISSUE CONSUMED OR REMOVED BY LARVAE

The tunnels of 41 fully grown larvae which had spent practically their entire feeding period in isolated sweet corn and dent field cornstalks, were measured and found to average 8.6 inches in length. (See Table 14.) The tunnels of 35 of these larvae in sweet corn were found to average 0.2492 cubic inches in volume, and the tunnels of the 6 larvae in dent field corn averaged 0.1690 cubic inches in volume. It was not possible to determine the relative proportion of plant tissue which had actually been consumed by the larvae in comparison with the proportion of the tissue which had been bored out and cast aside during the excavation of the tunnel.

DISTRIBUTION OF LARVAE IN THE PLANT

While the host plant is green and succulent, it may be entered and tunneled by the feeding larvae at practically any point, but as the plant nears maturity and begins to dry out in its upper portions, or breaks over as a result of larval injury, the larvae exhibit a tendency to migrate to the lower and more succulent portions.

On September 27, 1921, 78 per cent of the stalks were found to be infested in a 4-acre field of flint field corn at Stoneham, Mass., averaging 5.3 larvae per infested stalk. A total of 65.4 per cent of the larvae were distributed in the lower third of the infested stalks and the remaining 34.6 per cent in the upper two-thirds of the stalks. In this same field and on this same date a record was made of the relative distribution of the larvae in the stalks, ears, and ear stems of 10 plants showing average infestation. In these 10 plants 63.3 per cent of the larvae were distributed in the stalks, 23.3 per cent in the ears, and 13.3 per cent in the ear stems. An analysis of the larval distribution in partly matured plants of dent, flint, and sweet corn which were dissected at Sandusky, Ohio, during the period from August 12 to September 1, 1924, showed that in a total of 474 larvae involved in these dissections 17.29 per cent were distributed in the lower quarter of the stalks, 18.77 per cent in the lower middle quarter of the stalks, 16.66 per cent in the upper middle quarter, 16.45 per cent in the upper quarter, 10.97 per cent in the tassel, and 19.82 per cent in the ears.

The relative distribution of the larvae in the stalks and stubble is subject to considerable variation in accordance with the height of the stubble left after cutting, the date stalks were cut, and the stage of development of the plant when cut. There is also a certain amount of larval migration to stubble from corn which is cut and stacked in the field, and from infested weeds or other plants growing near by. For this reason the percentage of the infested stubble (fig. 45) in certain fields sometimes exceeds the percentage of infested plants determined before cutting. During the late summer of 1921 counts were made of larval infestation in the stubble of 15 fields of sweet and field corn in New England soon after the plants were cut. Field counts in these same fields previous to cutting showed that an average of 68.4 per cent of the stalks were infested. An examination of the stubble after cutting showed that 31.7 per cent contained living larvae. The stubble in these fields ranged from 5 to 12 inches in height.

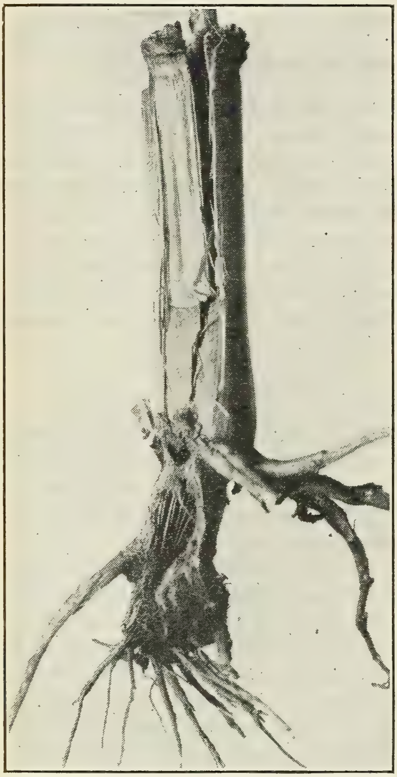

FIG. 45.—European corn-borer larva at base of corn stubble; entrance hole just above

In western New York an examination of the stubble in 30 fields of dent and sweet corn during the period from August 8 to November 11, 1923, showed that 6.63 per cent of the stubble was infested, containing on an average 7.78 larvae per 100 stubble. Field counts in these same fields previous to cutting demonstrated that an average of 15.16 per cent of the stalks were infested, containing an average of 19.75 larvae per 100 stalks. Comparing the average number of larvae left per 100 stubble with the average number of larvae per 100 stalks, it will be noted that 39.39 per cent of the total larval population was left in the stubble. In these 30 fields the stubble ranged from 2 to 18 inches high, with an average height of about 7 inches. A similar comparison between the larval population in the stalks and in the stubble of 36 dent and sweet cornfields in western New York during 1924 showed that 16.12 per cent of the total larval population was left in the stubble. In these 36 fields the stubble ranged from 2 to 10 inches high, with an average height of about 6.2 inches.

Examinations made of standing cornstalks in Ohio during the period from September 10 to November 3, 1924, showed a pronounced movement of the borers to the lower part of the stalks, as detailed in Table 30.

TABLE 30.—*Distribution of larvae of the European corn borer in cornstalks in Ohio during period from September 10 to November 3, 1924*

Date of observation (1924)	Total larvae	Larvae 3 inches and below		Larvae 6 inches and below		Larvae 9 inches and below		Larvae 12 inches and below		Larvae 15 inches and below		Larvae 18 inches and below		Larvae 21 inches and below		Larvae 24 inches and below		Larvae 27 inches and below	
		Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Sept. 10 to 16	547	16	2. 9	40	7. 3	61	11. 1	91	16. 6	108	19. 7	124	22. 7	140	25. 6	168	30. 7	185	33. 8
Sept. 17 to 25	226	10	4. 4	23	10. 2	26	11. 5	46	20. 4	53	23. 5	67	29. 6	68	30. 1	85	37. 6	95	42. 0
Oct. 1 to 8	173	7	4. 0	15	8. 7	25	14. 5	41	23. 7	46	26. 6	61	35. 3	67	38. 7	78	45. 1	95	54. 9
Oct. 23	135	7	5. 2	23	17. 0	36	26. 7	52	38. 5	67	49. 6	81	60. 0	85	63. 0	92	68. 2	----	----
Nov. 3	110	11	10. 0	25	22. 7	36	32. 7	46	41. 8	63	57. 2	73	66. 4	78	70. 9	82	74. 6	----	----

In general the percentage of total larval population present in the stalks up to and including 18 inches from the ground increased approximately threefold between September 10 and November 3, and similar increases in larval population occurred in that portion of the stalks situated from 18 to 24 inches of the ground during this same period. (Table 30.) The high percentage of larvae present in that portion of the stalk up to and including 6 inches from the ground late in the season is also very impressive and serves to emphasize the necessity of cutting stalks low and as early in the season as possible. The greater proportion of the corn stubble in the machine-cut fields of Ohio and Michigan is at least 6 inches in height, while 24 inches is about the maximum height in fields cut by hand methods.

POSSIBILITY OF SPRING FEEDING BY OVERWINTERING LARVAE

In a previous publication (*71*) dealing with the habits of *Pyrausta nubilalis* larvae, reference has been made to the spring "feeding" of overwintering larvae. After a more detailed observation of the spring activities of the overwintering larvae, it appears that no real feeding occurs at this period and that the frass ejected from the larval burrows is composed of material which has been gnawed and cast aside during the process of preparing quarters for pupation. This frass is composed of rough angular particles, in contrast to the smooth, rounded pellets predominating in the normal excrement of actively feeding larvae. A histological study of the internal tract of overwintering larvae reveals an entire absence of solid food, and, furthermore, that important structural changes have occurred in the digestive tract of the larvae after active feeding ceased in the fall. The most important modification occurs in the ventriculus and rectum of the larva, and is of such a nature as to render these organs much more simple and less specialized in structure, the rectum losing for the most part its musculature. According to present knowledge, it appears improbable that overwintering larvae could successfully digest food or evacuate unassimilable matter in the spring. This conjecture is confirmed in a measure by inability to find larvae feeding on new growth in the spring, after they have passed through the winter. A spring examination of the digestive tracts of overwintering larvae found in the field revealed an entire absence of solid food, and when these larvae were isolated from any boring medium whatever and supplied with proper moisture conditions, they pupated and emerged as normal adults.

Repeated experiments have been performed in which overwintering larvae were confined during April and May in small cages with green succulent stalks of rhubarb, celery, Rumex, and Polygonum. None of these individuals fed upon or entered these plants, although rhubarb, celery, Rumex, and Polygonum are preferred hosts of the active feeding larvae during the summer.

Field examinations during April and May of rhubarb, spinach, and early spring weeds growing closely adjacent to plant remnants containing overwintering larvae failed to show any infestation in these plants by such larvae.

DURATION OF LARVAL LIFE WITHOUT FOOD

The larvae of *P. nubilalis* are capable of maintaining life without food for a considerable period of time during their active development. This is especially true of larvae in the later instars. By isolating, in individual cages, a large series of first-generation larvae of each instar, it was determined that the average duration of life without food for the first instar was 1.95 days, second instar 5.5 days, third instar 6.7 days, fourth instar 8.1 days, fifth instar 22.8 days, and for the sixth instar 31.3 days. In this series newly hatched larvae were used for the first instar and newly molted larvae for each of the subsequent instars. Pieces of damp blotting paper provided suitable moisture conditions in each cage.

MOLTING

When tunneling inside its host plant, the larva molts within its tunnel near the last feeding place. Where the larva is feeding upon or close to the surface of its host plant, as frequently occurs during the early instars, molting usually takes place inside a thin silken web with which the larva surrounds itself for protection or concealment. Certain individuals in all instars have also been observed molting on the outside of the host plant without any other protection than that afforded by fragments of frass or a few strands of silk spun by the larva previous to molting.

LARVAL MIGRATION

The migration of *Pyrausta nubilalis* larvae from one part of the host plant to another part of the same plant, or to near-by plants, has already been discussed. In addition to this very localized migration, the larvae, especially in their later instars, frequently leave their host plants when such plants are disturbed, or when such hosts become unsuitable for food or shelter through decay or as a result of the drying out of the plant tissues. This migration is especially likely to occur (1) where infested cornstalks are being collected in the fields; (2) where such stalks are left in piles of " stacks " in the field, in the barnyard or under shelter, with the consequent decay through excessive moisture, or the drying out of the plants when protected from rain and snow; (3) when badly infested plants collapse and break over in the field; (4) after infested plants with comparatively small stems, such as oats and some of the weeds, are cut while in a green condition, with the consequent rapid withering or shriveling of the stems; (5) during the handling and shipment to market of infested plant products such as sweet corn ears or beets with tops; (6) from certain plant products, such as celery, after they are placed in underground pits; (7) from infested material which has been buried in the soil. This last is especially likely to occur where such material is buried or plowed under in the spring, or in the early fall to about November 1. Much of this migration is nocturnal, an interesting habit which the species may have developed in an endeavor to escape natural enemies which are more active during the daylight hours. Observations conducted at night in severely infested fields of corn have revealed great activity on the part of the larvae at this time. Where infested cornstalks or other plant remnants are cut and gathered in large piles during the fall and left in this condition in the field all winter, many of the contained larvae migrate to the outer and drier layers of the pile, or to adjoining shelter, in order to escape the excessive moisture prevailing in the interior of the pile. These outer layers usually are dry enough to be burned easily during late April or early May and thus destroy a large percentage of the borers contained therein.

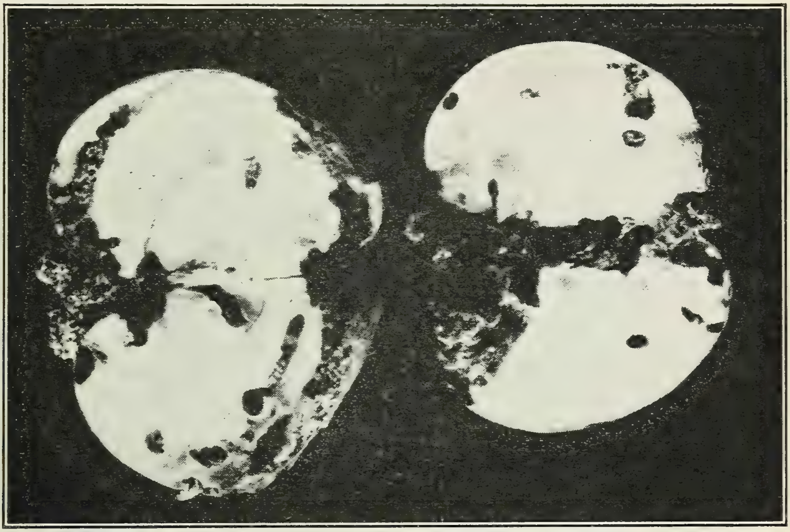

FIG. 46.—Windfall Baldwin apple infested by migrating European corn-borer larvae. A common occurrence in areas of severe infestation. Medford, Mass., September 15, 1922

When the migrating larvae are only partially grown they may enter and feed upon any of the host plants of the species, providing such plants are in a green and succulent condition. When, however, the migrating larvae are fully grown and have ceased feeding, they may enter almost any plant material (fig. 46) which affords suitable shelter, or they may seek shelter in various locations, as will be subsequently shown.

The actual distance traversed by migrating larvae in the field has not been determined with accuracy, although infested cornstalks have been found at a distance of about 15 feet from the location of the nearest known original egg cluster in a very lightly infested corn plat. In a series of controlled experiments wherein crawling larvae of each instar except the second were restricted to sheets of paper from 5 to 6 feet in length, without food, until death resulted, the average distance covered by larvae in the first instar was 31 feet 3 inches; third instar, 118 feet 1 inch; fourth instar, 79 feet 8 inches; fifth instar, 170 feet; and sixth instar, 97 feet 1 inch. These experiments, of course, do not give reliable information relative to the probable migrating ability of the larvae in the field and are only indicative as showing their power of locomotion.

HIBERNATION

The European corn borer normally passes the winter as a full-grown larva within the tunnel made in its host plant during the previous summer and fall. If, however, the host-plant material is unduly disturbed during the progress of field work, or if for any other reason the plants containing the larvae do not afford suitable quarters for winter shelter, many of the larvae migrate from their hosts and enter other plants. Under conditions of severe infestation the larvae have entered such woody stemmed plants as blackberry, raspberry, sumac, elderberry, and grape. If suitable plants are not available for winter shelter, the larvae often burrow into such objects as the walls and crevices of buildings, fences, and posts. Here they form short tunnels in which to pass the winter. When more suitable winter quarters are lacking, the larvae sometimes secrete themselves in loose leaves, under the loose bark of trees or fence posts, and underneath rubbish, clods of soil, loose stones, and similar objects. Here they may, or may not, inclose themselves entirely or partially with a rough silken web. Many of these larvae which seek shelter in locations other than plants, as mentioned above, have been found by experimentation to pass the winter successfully and subsequently to pupate and emerge as moths; providing that the moisture conditions of their habitat were suitable for normal hibernation and pupation.

In every instance under observation all of the hibernating larvae were in the last instar. No case of molting in the spring has been observed.

LARVAL MORTALITY DURING HIBERNATION

Dissection of *Pyrausta nubilalis* larvae during their period of hibernation has revealed that the vital organs are surrounded with a layer of tissue resembling fat. Apparently this fatty material greatly aids the hibernating larvae not only in surviving the adverse natural conditions to which they are exposed during this period but also supplies available means for carrying on the metabolism which occurs during this long period of comparative inactivity. It may also aid the hibernating larvae in resisting such artificial influences as fumigation and heat.

The normal percentage of winter mortality in plants left in natural position in the field is comparatively low. Table 31 gives data relative to the winter mortality for a five-year period in representative localities of the New England area. These counts, with exceptions noted, were taken during the spring of each year in corn and weeds left in their natural position in the field. Less than 1 per cent of the overwintering larvae were parasitized, so this factor may be practically ignored.

TABLE 31.—*Winter mortality of Pyrausta nubilalis larvae in New England*

Winter period	Total larvae counted	Total larvae dead	Per cent of larval mortality
1919–20	1, 231	110	8. 9
1920–21	1, 776	133	7. 5
1921–22	2, 478	233	9. 4
1922–23	10, 100	838	8. 3
1923–24 [1]	10, 989	440	4. 0
Total	26, 574	1, 754	
Five-year average			6. 6

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[1] Limited to counts in experimental plats of corn.

Table 31 shows that the average winter mortality for the period was 6.6 per cent. This figure applies to plants which were in a natural position; that is, plants which were standing erect, broken over, or lying upon the surface of the soil. When infested cornstalks or other plant remnants are cut and gathered and placed in large piles during the fall and left in this condition all winter, a considerable proportion of larval mortality sometimes occurs in the interior of such piles when they are exposed to conditions of excessive moisture. It is not possible, however, definitely to attribute this killing to true winter mortality, because other influences, such as mechanical injury during handling or fermentation of the plant material may contribute to this result. In a recent publication (*5*) Barber discusses the importance of winter mortality in the natural control of the European corn borer in New England.

COMPARATIVE WINTER MORTALITY ACCORDING TO POSITION OF HOST

In the course of experiments carried on during the winter of 1920–21, with the object of ascertaining the comparative winter mortality of larvae in cornstalks standing erect and cornstalks lying upon the surface of the soil, it was found that in the former the winter mortality was 1.5 per cent and in the latter 4.3 per cent. In cornstalks standing erect there was no appreciable difference in the percentage of mortality between larvae inhabiting the lower and upper portions of the stalks.

COMPARATIVE WINTER MORTALITY ACCORDING TO TOPOGRAPHIC LOCATION OF HOST

During the spring of 1921 counts for winter mortality were made in localities representing typical conditions of lowland areas, highland areas, and coastal areas. These counts were all made in cornstalks left in the field of the New England area under natural conditions. According to the figures obtained in these counts, the percentages of winter mortality on lowland areas, highland areas, and coastal areas were 19.9, 16, and 12.8 per cent, respectively. The average winter mortality for the New England area, including larvae from cornstalks and weeds, was 7.5 per cent during this period.

COMPARATIVE WINTER MORTALITY IN PROTECTED SITUATIONS

Reference has previously been made to the habits of certain of the migrating larvae in seeking winter shelter by boring into various wooden objects and by secreting themselves underneath rubbish, clods of soil, loose bark of trees, and similar situations. In order to obtain information concerning the probable percentage of winter mortality among such larvae, a series of experiments were started during the late fall of 1919 in which large larvae were confined in cages containing soil, sawdust, dry manure, dry leaves, dry grass, moss, and wooden objects. Larvae were also confined in an empty wooden box. These cages were kept under a shelter, but otherwise they were exposed to winter conditions. A similar cage of infested cornstalks, kept under the same conditions, was used as a check. The average winter mortality in the test cages was 13.3 per cent and in the check cage 7.6 per cent.

COMPARATIVE WINTER MORTALITY IN DIFFERENT SPECIES OF HOST PLANTS

Table 32 shows the comparative winter mortality of the larvae in different species of host plants left in a natural position in the field during the winter of 1921–22 in the New England area.

TABLE 32.—*Comparative winter mortality of larvae of the European corn borer in different species of host plants during winter of 1921–22 in New England*

Host plant	Number of localities	Number of larvae counted	Total larvae dead	Per cent winter mortality
Corn	9	901	100	11.0
Xanthium	5	644	33	5.1
Echinochloa	4	273	30	10.9
Polygonum	2	150	4	2.6
Bidens	2	210	16	7.6
Amaranthus	2	200	42	21.0
Chenopodium	1	100	8	8.0
Total		2,478	233	
Average				9.4

According to the data shown in Table 32, there was some variation in the percentage of mortality in different host plants. No explanation can be given for the cause of this apparent variation. The mortality in the weeds in this series of experiments was 8.4 per cent, in comparison to a mortality of 11 per cent in corn.

LARVAL MORTALITY WHEN FROZEN IN ICE

In order to determine the mortality of *P. nubilalis* larvae contained in material frozen in ice, several series of experiments were performed in which infested cornstalks were placed in bodies of water during the late fall in such a position that they were subsequently frozen in the ice. Examinations of the larvae contained in these stalks were made once a month during the period from December to April, and it was found that the mortality for the first three months was practically equal to that of the check material left in a natural position. Beginning from about the 1st of March, however, the mortality of the larvae contained within the frozen-in stalks increased very rapidly. When the last series were examined during the first week of April less than 1 per cent of the larvae were alive. The heavy mortality occurred, therefore, during the period when the larvae would normally have become active preparatory to pupation.

WINTER MORTALITY OF LARVAE IN STORED MATERIAL

Jablonowski [9] has recommended, as a possible means of control to be applied to overwintering larvae, the storing of cornstalks in a comparatively weather-tight shed or barn until after the normal time for emergence of the moths the following spring. His idea is that the larvae contained in such stored material would be unable to complete their development when deprived, during the winter and early spring, of the moisture which is available to those larvae overwintering in the normal locations and which is so essential for the completion of histolysis.

The experiments which have been carried out up to the present time to determine the advisability of such a recommendation have shown that when larvae in stalks are stored in the insectary, or even more thoroughly inclosed structures for the winter season, a reduced percentage of them, ranging from 4 to 30 per cent, were able to complete their development, and that these were considerably retarded beyond the normal seasonal development that would be expected in the field.

The percentage of larvae able to pupate and successfully emerge as adults was decreased when stored material was kept under heated, low-humidity conditions, such as those prevailing in a room of the laboratory. As will be discussed in a paper dealing with experiments upon the hibernation period, the cumulative effect of these various conditions of storing not only induces an immediate reaction reflected by increased mortality and delayed pupation but also has the effect of delaying seasonal development during the subsequent growing season. In fact, only 9 per cent of the individuals which for two consecutive seasons had been denied the normal precipitation conditions during hibernation were able to develop the two generations normally occurring in this area.

Larvae without protection of cornstalks, ears, or similar covering seem unable to withstand either of the two conditions just discussed, and usually shrivel and dry up after the long exposure from fall to the following spring.

PUPATION

Pupation normally occurs within the tunnel made by the larva in its host plant. The larvae of the overwintering brood pupate in the tunnels which they have occupied during the winter, unless the condition of the host material in the spring is such that they are forced to migrate and seek similar but more suitable quarters free from extremes of moisture or desiccation. The summer-brood larvae normally pupate not far from the last feeding place in their tunnels. Larvae of both broods may also pupate in protected places on the exterior of their host plant, such as between the silks on the ears of corn, between the leaf sheaths and the stalks, or between overlapping leaf blades of corn or other plants. Full-grown larvae which migrate to situations removed from the plant and bore into wood or similar material for shelter usually pupate within these shelter tunnels, provided that the moisture conditions of the shelter medium are suitable for pupation. The same statement applies to full-grown larvae which migrate from the plant and secrete themselves in the cracks and crevices of lumber or underneath rubbish of various kinds.

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[9] See footnote 1.

COCOON FORMATION AND LARVAL CHANGES

When preparing for normal pupation the larva first closes the entrance to its tunnel with a thin silken partition and then retreats into the tunnel, where it forms a thin silken cocoon. Larvae which pupate in situations lacking the protection of a tunnel partly or entirely inclose themselves with similar cocoons. Some of the larvae spin such a meager quantity of silk that it is an exaggeration to describe the fabrication thus formed as a real cocoon.

When the cocoon is completed, the larva attaches itself thereto by means of the crochets on the anal legs, and then passes into a short semiquiescent stage preparatory to pupation. During this stage the head becomes inflexed and the use of the thoracic and abdominal legs is lost, while the abdominal segments become greatly swollen and show distinctly the outlines of the pupal abdomen.

PROCESS OF PUPATION

As a result of pressure exerted from within, the larval skin splits along the dorsal line of the head and thoracic segments, and also down each side of the front, thus liberating the emerging pupa. As soon as it is freed from the larval skin the newly formed pupa revolves on its longitudinal axis two or three times, in this manner firmly attaching its cremaster to the cocoon at the point formerly occupied by the anal feet of the larva. Out of a total of 141 pupae under observation in vertical tunnels, 118 individuals formed with the head pointing upward, and the remaining 23 individuals with the head downward. The newly formed pupa is nearly white in color with a longitudinal pink line down the dorsum. Permanent coloration proceeds very rapidly after emergence and in five or six hours the pupa is fully colored. Mature pupae vary from light brown to dark brown in color.

ADULT HABITS

EMERGENCE

The emerging moth pushes off the head of the pupal skin until its head, thorax, and bases of the wing pads are visible. Here it rests for a short period before struggling completely out of the pupal skin. Ten individuals under observation required an average of two minutes for complete emergence. After emergence the moth escapes from its cocoon and crawls to the surface of the plant, provided pupation occurred within a tunnel. After reaching the surface the moth clings to some convenient object until the wings become fully expanded and dried. Within a period of from two to three hours after emergence it is prepared for flight.

PROPORTION OF SEXES

Table 33 gives data relative to the proportion of sexes as recorded from insectary reared material at Arlington, Mass., during the period from 1918 to 1921.

TABLE 33.—*Proportion of sexes of Pyrausta nubilalis at Arlington, Mass. (two generations)*

Generation	Number of individuals	Per cent females	Per cent males
Second generation, 1917–18	342	49.5	50.5
First generation, 1918	366	57.6	42.4
Second generation, 1919–20	221	37.0	63.0
First generation, 1920	134	45.5	54.5
Second generation, 1920–21	933	48.0	52.0
First generation, 1921	45	51.2	48.8
Total	2,041		
Average		48.7	51.3

Table 33 shows that of the individuals under observation during a three-year period at Arlington, Mass., the sexes occurred in about equal proportions, although in the spring brood the preponderance of males is marked. In each group under observation the males greatly outnumbered the females during the first part of the seasonal emergence period.

Relative to the proportion of sexes in the one-generation areas, the adult emergence from 234 pupae collected at Scotia, N. Y., during the spring of 1920 consisted of 114 females, or 48.7 per cent; and 120 males, or 51.3 per cent. At Silver Creek, N. Y., notes were made upon the sex of 690 adults which emerged during the experimental work throughout the period 1921 to 1924. Of this number 350, or 50.7 per cent, were females and 340, or 49.3 per cent, were males. At Sandusky, Ohio, 53.3 per cent of the adults emerging from experimental material during 1924 were females and 46.7 per cent were males. A total of 809 adults were included in this group. In each group under observation in these areas the males emerged sooner than the females in the proportion of nearly two to one, but as the emergence period advanced the females predominated in numbers.

COPULATION

Copulation usually occurs within a period of 12 hours after emergence from the pupa. During this act the male assumes a position to one side of the female and turns his abdomen at right angles with the body, meanwhile thrusting out the genital organs. When coition is successful, the male assumes a position directly to the rear of the female, the long axis of each being in a straight line. Three pairs of moths under observation remained in copula for an average period of 2 hours and 23 minutes. The moths have been observed in copula at nearly all hours of the day, but this usually occurs during the late afternoon and evening, at which time they are most active.

MATINGS NECESSARY TO FERTILIZE TOTAL COMPLEMENT OF EGGS

A single mating was found to be sufficient to insure the normal percentage of fertility of the total complement of eggs deposited by each female in a series of experiments wherein single pairs of newly emerged moths were confined in separate lantern-globe oviposition cages. Each of these cages contained a virgin female, which had emerged from an individual glass vial cage, and a male which had emerged from similar cage. These cages were kept under observation and as soon as copulation occurred the male was removed. It is not known whether more than one mating normally occurs in the field, but in confinement several matings have been observed in instances where pairs of moths were retained in cages throughout their period of life. The fact that a single mating appears to be sufficient to insure the fertility of the eggs apparently would enable gravid and fertilized females to perpetuate the species if dispersed for a long distance by flight or by carriage.

NUMBER OF FEMALES FERTILIZED BY EACH MALE

In order to determine the number of females fertilized by each male, a vigorous newly emerged male was placed in an oviposition cage with a newly emerged female. As soon as copulation occurred, the male was transferred to a similar cage also containing a virgin female. This process was repeated until the death of the male 19 days from the start of the experiment. During this period the male had mated with nine different females. The total complement of eggs deposited by the second, third, fourth, and sixth females used were fertile, whereas the eggs deposited by the first, fifth, seventh, and ninth females used were infertile. The eighth female died without depositing eggs. The other females in this series deposited a normal number of eggs. It will be noted, therefore, that the *Pyrausta nubilalis* male used in this experiment fertilized a total of four females. Even allowing for cage conditions, it seems probable that under natural conditions each male would fertilize several females.

OVIPOSITION

The average preoviposition period of *P. nubilalis* females in confinement varied from 2.6 to 5.1 days in Massachusetts, as shown in Table 24. Among the females under observation in confinement and in the field, oviposition was greatest during the period between dusk and midnight, and rarely occurred during the daylight hours. The eggs usually are deposited upon the undersides of the leaves of the host plant, although they have been found infrequently on the upper sides of the leaves and upon the stems of plants such as corn, rhubarb, and cocklebur, as well as upon the husks of ears of corn.

During the act of oviposition the female extrudes the ovipositor until its tip comes in contact with the leaf blade at the spot selected for egg deposition. She then stands still and vibrates the abdomen until the spherical egg appears at its tip. The egg is then quickly pushed against the leaf and tamped into place with the ovipositor. This operation changes the egg from its orginial spherical shape into a more flattened one. The remaining eggs of the cluster are then deposited in irregular rows, each egg overlapping the adjoining egg in the manner of shingles. The female rarely changes her position during the deposition of an egg cluster, as the flexibility of the abdomen allows quite a radius of movement.

PLANTS PREFERRED FOR OVIPOSITION

Although corn usually is preferred for oviposition, the eggs have been commonly found in the New England area on a variety of other plants, particularly rhubarb, spinach, beets, beans, potatoes, celery, dahlias, hemp, dock, smartweed, barnyard grass, pigweed, and cocklebur. Eggs have also been found occasionally upon most of the other host plants listed in the first three classes shown in Table 1. It has been observed that the moths usually prefer to deposit eggs upon plants bearing relatively large leaves or dense foliage. Doubtless this choice is somewhat influenced by the fact that plants of this character afford protection to moths from the sun and wind during the day. Preference is also shown for that portion of the plant on the lee or opposite side from the prevailing winds. Oviposition is not confined to plants affording shelter during the day, however, as eggs are sometimes found upon young corn plants not more than 6 inches in height. During late May and early June in New England, dock, smartweed, rhubarb, and spinach are the most favored plants for egg deposition by the early emerging females. At this time corn and other preferred host plants are just starting their development.

In the one-generation areas of eastern New York and the Lake Erie region, egg clusters rarely have been found on plants other than corn.

In New England a few egg clusters have been found on plants in which the larvae are not known to feed under natural conditions, namely, dandelion (*Leontodon* spp.), horseradish (*Radicula armoracia*), lettuce (*Lactuca sativa*), plantain (*Plantago* spp.), oxalis (*Oxalis* spp.), and rye (*Secale cereale*).

OVIPOSITION HABITS OF FEMALES IN CONFINEMENT

In confinement the moths frequently deposited eggs upon the interior of lantern-globe cages as well as upon the leaves of susceptible host plants which were provided for egg deposition. When the moths were confined in cages constructed of transparent paper and lacking any vegetation, but which were adequately supplied with moisture, they readily deposited their egg clusters upon the paper walls of these cages. This habit of the moths was utilized to advantage when large numbers of egg clusters were needed for egg-parasite and other studies.

TOTAL NUMBER OF EGGS DEPOSITED BY EACH FEMALE

Judging from oviposition records obtained in confinement, *Pyrausta nubilalis* is very prolific. Tables 34 and 35 show the average, maximum, and minimum number of eggs which were deposited by the females of the first and second generations when confined in lantern-globe cages at Arlington, Mass., for each year during the period from 1918 to 1921, inclusive.

TABLE 34.—*Total number of eggs deposited by first-generation Pyrausta nubilalis females in New England*

	Number of females under observation	Average total eggs per female	Maximum total eggs per female	Minimum total eggs per female
First generation of—				
1918	17	439	903	53
1919	109	378	828	72
1920	93	487	874	52
1921	37	562	1,934	44
Total	256			
Average		448		

TABLE 35.—*Total number of eggs deposited by second-generation Pyrausta nubilalis females in New England*

	Number of females under observation	Average total eggs per female	Maximum total eggs per female	Minimum total eggs per female
Second generation of—				
1917–18	11	344	724	107
1918–19	69	335	1,192	43
1919–20	121	358	895	55
1920–21	17	271	465	4
Total	218			
Average		344		

The average, maximum, and minimum number of eggs which were deposited by the females of *P. nubilalis* in the one-generation areas when confined in lantern-globe cages at Silver Creek, N. Y., and Sandusky, Ohio, during 1923 and 1924, are shown in Table 36.

TABLE 36.—*Total number of eggs deposited by Pyrausta nubilalis females at Silver Creek, N. Y., and Sandusky, Ohio* (*one generation*)

Place	Year	Total females in experiment	Total eggs deposited	Average total eggs per female	Maximum total eggs per female	Minimum total eggs per female
Silver Creek, N. Y	1923	50	10,900	218	1,000	12
Do	1924	50	17,714	354	1,061	12
Sandusky, Ohio	1923	25	8,056	322	694	26
Do	1924	50	29,250	585	1,075	2

The averages shown in Table 36 were computed from the number of females in the experiment. In the Silver Creek experiments 11 females in the 1923 series and 8 females in the 1924 series did not deposit eggs. In the Sandusky experiments 1 female in the 1923 series and 3 females in the 1924 series did not deposit eggs.

NUMBER OF EGGS PER CLUSTER

The majority of the egg clusters collected in the field in New England have contained from 15 to 20 eggs, although the number of eggs per cluster is subject to considerable variation. From 1 to 162 eggs have been found in individual clusters. Jablonowski [10], quoting from observations made by his assistant, Gabriel Bako, states that in Hungary "each cluster contained a minimum of from 22 to 35 eggs." Table 37 gives data relative to the average number of eggs per cluster deposited by females in confinement at Arlington, Mass.

TABLE 37.—*Average number of eggs of Pyrausta nubilalis per cluster, New England, 1918 to 1921*

Generation	Number of clusters counted	Average number of eggs per cluster	Average maximum number of eggs per cluster per female
Second generation, 1917–18	172	20.0	34.0
First generation, 1918	431	17.3	34.6
Second generation, 1918–19	1,666	13.9	31.2
First generation, 1919	2,884	14.0	33.0
Second generation, 1919–20	3,539	12.2	40.0
First generation, 1920	3,255	13.9	30.8
Second generation, 1920–21	260	19.2	38.7
First generation, 1921	1,127	23.4	35.2
Total	13,334		
Average		14.6	

Table 37 shows that the average number of eggs per cluster varied from 12.2 to 23.4 in the different generations of females under observation, with an average of 14.6 eggs per cluster for the entire series. The last column in this table pertains to the average maximum number of eggs per cluster deposited by any one female in the generation.

At Silver Creek, N. Y., there were an average of 14.5 eggs per cluster in 747 egg clusters deposited in confinement during 1923, and an average of 16.7 eggs per cluster in 1,060 egg clusters deposited under the same conditions in 1924. Comparative figures for Sandusky, Ohio, observations show an average of 14 eggs per cluster in 575 egg clusters during 1923, and an average of 16.8 eggs per cluster in the 1,746 egg clusters upon which observations were made in 1924. A total of 731 egg clusters collected in the field in Ohio during 1924 contained 15.5 eggs per cluster on an average. The average number of eggs per cluster in the one-generation areas of New York and Ohio compares very closely with the average for the two-generation area of New England.

DAILY RATE OF OVIPOSITION

In confinement the daily rate of oviposition varied with different females and according to the temperature conditions. In some instances a single female deposited several egg clusters within a 24-hour period, whereas in other instances a period of several days elapsed between the deposition of successive egg clusters. Table 38 gives data relative to the daily rate of oviposition of females confined in individual lantern-globe cages at Arlington, Mass.

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[10] See footnote 1.

TABLE 38.—*Daily rate of ovisposition of P. nubilalis females, New England, 1918 to 1921*

Generation	Number of females under observation	Average oviposition period in days	Average number of days during oviposition on which no eggs were deposited		Average number of eggs per day during oviposition period	Maximum eggs deposited on any one day (average)	
			Number	*Per cent*		*Number*	*Per cent*
Second generation, 1917–18	11	12.1	3.8	31.4	28.4	87.0	25.3
First generation, 1918	17	13.4	4.5	33.6	32.7	119.9	27.3
Second generation, 1918–19	68	12.7	4.8	37.8	26.4	96.0	28.6
First generation, 1919	109	11.8	4.0	33.9	31.6	123.0	32.5
Second generation, 1919–20	121	14.1	4.6	32.7	25.4	80.8	22.6
First generation, 1920	92	9.5	1.6	16.8	51.3	153.3	31.5
Second generation, 1920–21	17	10.6	4.6	43.4	27.4	68.2	23.5
First generation, 1921	42	13.0	3.4	26.1	52.3	142.4	20.9
Total	477						
Average		12.2	3.7	30.3	34.7	113.1	26.3

The data given in this table show that for approximately one-third of the days of the oviposition period the moths under observation did not deposit any eggs and that an average of from 22.6 to 32.5 per cent of the eggs were deposited in one day by moths of the different generations.

Approximately 23.7 per cent of the moths of the second generation 1919–20 series, shown in the table, deposited the greatest number of eggs per day during the first day of their oviposition period, whereas 55.1 per cent of such moths deposited the greatest number of eggs per day during the first five days of their oviposition period. One individual of this series deposited 330 of her total complement of 517 eggs on the first day of her oviposition period, and the remaining eggs were deposited throughout a period of 14 days. The average duration of the oviposition period of this series of moths was 14.1 days. In the 1920 series of first-generation moths 42.4 per cent deposited the greatest number of eggs per day during the first day of their oviposition period, whereas 81.5 per cent of these deposited the greatest number of eggs per day during the first five days of their oviposition period. The average oviposition period of this series of moths was 9.5 days.

The long period of fertility of the moth is important because it results in larvae of several instars being present in the same field, and often on the same plant simultaneously, thus causing a difficulty in evolving control measures having for their objective the destruction of the young larvae before they enter the plant. This fact also increases the opportunity of dispersion by flight or carriage of the gravid females.

FLIGHT

The moths are essentially nocturnal in habit, although individuals have been observed taking short flights during daylight. Normally, however, they seek shelter during the day underneath the leaves of weeds, grasses, and cultivated crops. They are often found lurking in the grass headlands adjacent to fields of corn and other crops. When disturbed during the day, they make short flights, close to the ground, for distances of from 10 to 20 feet, and eventually seek cover again.

The moths are most active during warm nights and comparatively inactive on cool or cold nights or during heavy winds. The daily period of greatest flight activity begins shortly after dusk and does not materially decrease until after three or four hours of darkness. Only a few moths have been observed in flight during the later hours of the night, although this observation may have been influenced by the difficulty of observing the moths at this period. During the month of June the moths were most active in laboratory cages from 9 p. m. until about 11 p. m. and more or less active until 4.30 a. m.

The flight of the sexes is somewhat different in character. Since the female is heavier her flight is direct, while that of the male is more rapid and of an erratic zig-zag character.

DISTANCE OF FLIGHT

In the course of experiments to determine the flight abilities of the moths it was found that both sexes possess the power of sustained flight for considerable distances either in single flights or in a series of flights. Flight usually occurs in the direction of the prevailing wind, although moths have been observed flying against a light wind.

Previously it has been stated that when dislodged during the day the moths usually fly only a few feet before seeking shelter. During their daily period of active crepuscular flight, however, certain of the moths fly much longer distances, although it was not possible accurately to gauge the distance of such flights because of the dim light. In order, therefore, to obtain indicative information regarding the flight capabilities of moths in single flights it was necessary to liberate moths during the day in situations where shelter was absent. For this purpose a stretch of low, wide, sandy beach was selected, which was devoid of shelter within 200 yards, and moths of both sexes were liberated at the edge of the water during low tide at a time when a light breeze was blowing off the water. Under these conditions individual moths were traced in single flights in the direction of the prevailing breeze for a maximum distance of 258 yards and to an elevation of approximately 50 feet before they were lost to view. All of the moths used in this experiment took flight directly after liberation and flew rapidly with the prevailing breeze, gradually ascending to elevations of from 15 to 50 feet before being lost to view. At this point they were flying strongly, and it seems probable that they covered at least 300 yeards from the point of liberation before alighting.

In these and in similar experiments, little difference was observed between the flight capabilities of the sexes. The males as a rule took flight quicker than the females after liberation and flew more rapidly, but the females were more direct in their flight and appeared to cover at least an equal distance. All of the females used in these experiments were gravid.

Flight Experiment on Cape Cod

Prior to the summer of 1921 several experiments, having for their object the recovery of artificially stained moths liberated from a central point, had shown that the moths were capable of a total flight of at least three-fourths of a mile. It was believed, however, that these experiments did not indicate the real limits of dispersion of the moths by flight, keeping in mind their relatively long period of life and the distance which they have been observed to fly in single flights. In order, therefore, to obtain additional information upon this point, a total of 8,650 moths stained with an aqueous solution of carbol fuchsin (acid) were liberated from a central point at Truro, Mass., on Cape Cod, during August, 1921. This region was selected for the experiment on account of the open nature of the country and the fact that areas of corn and other favorite host plants were few and far between. Although there is no evidence at present to indicate that high hills, large bodies of water, or densely wooded areas are barriers to the flight of the moths, yet it seemed advisable to select a region having as few of these potentially limiting factors as possible. The selection of Truro as the point of liberation was also influenced by the fact that the prevailing winds during August are from the southwest, which fact probably would influence the flight of the moths toward the open country to the northward, between Truro and Provincetown, 9 miles distant.

Recovery of the stained moths was attempted by systematically sweeping all susceptible plants and other vegetation likely to be frequented by the moths, in the surrounding country. The territory examined included that portion of Cape Cod lying north of Wellfleet. From the point of liberation it extended 10 miles northwest to the tip of the cape, 2 miles east to the ocean, 5 miles south, and 1 mile west to the ocean. As previous experiments had resulted in the recovery of the moths at a maximum distance of nearly a mile from the point of liberation, no examinations were made within this limit.

Table 39 gives the results of this experiment.

Table 39.—*Result of experiment in sweeping for stained Pyrausta nubilalis moths on Cape Cod, Mass.*

Direction	Maximum distance of examinations from point of liberation	Recoveries			Remarks
		Number of moths	Sex	Distance from point of liberation	
	Miles			*Miles*	
North	3.5	1	Female	3.0	Gravid. Swept territory to ocean beach.
Do	3.5	1	do	2.4	Not gravid.
Do	3.5	1	do	2.6	Gravid.
Northwest	10.0	1	Male	2.7	
Do	10.0	1	do	2.8	
Do	10.0	1	Female	4.7	Do.
Do	10.0	1	Male	5.0	
Northeast	2.0	None.			Swept territory to ocean beach.
East	2.0	None.			Do.
Southeast	5.7	None.			Do.
South	5.0	None.			
Southwest	2.3	None.			Do.
West	1.0	None.			

From this table it will be noted that, under the conditions of the experiment, moths of both sexes were recovered at a maximum distance of about 5 miles from the point of liberation, and that three of the moths recovered were gravid. During the period when this experiment was in progress the direction of the prevailing wind at the point of liberation was from the south and the southwest. This is believed to have influenced the flight of the moths in a general northerly direction, and may explain the failure to recover moths beyond the 1-mile limit at any other points of the compass.

Although 5 miles was the maximum distance at which a stained moth was recovered in this experiment, it is believed that they are capable of dispersing to greater distances during a single flight, or in a series of flights, under favorable wind conditions. In the summer of 1922 a similar experiment indicated that adults were capable of flights of at least 20 miles over water.

EFFECT OF NATURAL BARRIERS ON FLIGHT

It does not appear that ordinary natural barriers such as high hills, densely wooded areas, or bodies of water, constitute any appreciable barrier to the flight of the moths.

Although there is a tendency for the moths to disperse along valleys and areas of low ground, they have also been observed in active flight on the tops of high hills. Cornfields situated on the tops of hills west and north of Boston, Mass., at an elevation of from 200 to 400 feet, have in some instances been found to be infested to at least an equal extent with the cornfields on lower ground in the immediate vicinity. It is problematical whether the moths would be able to make flights over high mountain ranges.

Relative to the efficiency of densely wooded areas as barriers to flight, in some instances fields of corn which were totally or partially surrounded by wooded areas were infested to a lesser degree than fields in the vicinity which were not so situated. This apparent protection, however, was by no means universal, as certain other fields situated amid similar surroundings were found to have an average infestation for the vicinity. In one case moths were observed in flight during the late afternoon among the trees between the open spaces of a wooded area, approximately 300 yards wide, which separated two large cornfields. It was not possible actually to trace individual moths through these woods from one field to the other, but evidently this strip of woodland was not acting as a barrier to flight.

Judging from experimental observations, ordinary bodies of water do not act as barriers to the flight of the moths. During the progress of preliminary observations to determine this point, moths of both sexes were liberated from a boat during the daytime at a point in the center of a lake at Arlington, Mass. These moths, without exception, flew rapidly with the prevailing wind toward the nearest shore, approximately 800 yards distant, and were soon lost to view. When moths were experimentally placed upon the surface of the water they rode the waves for a few minutes, but after a few struggling movements of the legs and wings they took flight in a normal manner. Moths which were experimentally plunged beneath the surface of the water immediately came to the surface and eventually took flight. When moths were liberated at the edge of the water during a strong offshore wind, about 15 to 20 miles per hour, they attempted to fly inland against the wind, but in almost every instance they were borne aloft during their struggles and eventually carried over the water. In this experiment the moths were liberated upon a strip of ocean beach affording no protection from the wind, whereas in a similar experiment where a beach protected by a steep cliff approximately 50 feet high was selected, some of the moths succeeded in fighting their way back to land and disappeared over the edge of the cliff.

As a continuation of the investigations to determine the effectiveness of large bodies of water as barriers to the flight of the moths, as well as to determine their flight capabilities, a total of 60,988 stained moths were liberated at Manomet Point, Plymouth, Mass., during the period from June 5 to July 23, 1922. These liberations were made only while the wind was blowing offshore (southwest to southwest by west) toward the tip of Cape Cod (Provincetown). Before liberation the moths were stained with an aqueous solution of carbol fuchsin (acid) applied as a fine spray. The majority of the moths had recently emerged from a large collection of cornstalks and weeds kept in a barn near by, which had been altered to serve the purpose of an insectary. The sexes were about equally represented. At the Provincetown end three crews, comprising a total of 12 men, systematically swept all corn and other vegetation likely to be used as a shelter by the moths during the day, throughout that portion of Cape Cod extending from the tip of the cape to the village of Orleans. Especial attention was given to the cultivated fields and waste areas in the vicinity of Provincetown and Highland Light. During the progress of this sweeping a total of 474 adults were found, but only one, a male, showed unmistakeable evidence of the stain. This male was collected in corn on Bradford Street, Provincetown, on July 18, at an air-line distance of approximately 20 miles (fig. 47) across Cape Cod Bay from the point of liberation. From observations made at the time of liberation it was noticed that during the prevalence of strong offshore winds, reaching at times a velocity of 30 miles per hour, the moths attained a height of 50 feet or more, immediately after liberation, before being carried beyond the range of vision by the wind. Owing to the height attained and the influence of the wind, it seems possible that many of them were unable to alight when reaching Cape Cod, and were carried out to sea.

From what has been shown, it is evident that the moths are able to make flights to a considerable distance over bodies of water and that when necessary they are able to alight upon the surface of the water and again take flight. This facility may be an important factor in the dispersion of the insect along the Atlantic coast and in the Lake Erie region.

FEEDING HABITS OF ADULTS

In captivity the moths have been observed sipping the pure water, and also the sweetened water, which was sprayed on the plants and soil in their cages. Whether they feed under natural conditions has never been observed, but they have lived as long and deposited as many eggs in the cages where pure water was supplied as in the cages where sweetened water was substituted. The moths in captivity fed to a slight extent on honey and also upon the juices of various fresh and decaying fruits, but when these substances were used under natural conditions in an effort to attract the moths, only negative results were obtained. In Hungary Jablonowski[11] observed large numbers of *P. nubilalis* moths swarming, in the dusk of the evening, over blossoming fields of clover, alfalfa, and potatoes. His explanation of this occurrence was that the moths were drinking the dew found on the leaves and flowers by night. It is also possible that the moths were sipping nectar from the flowers of these plants.

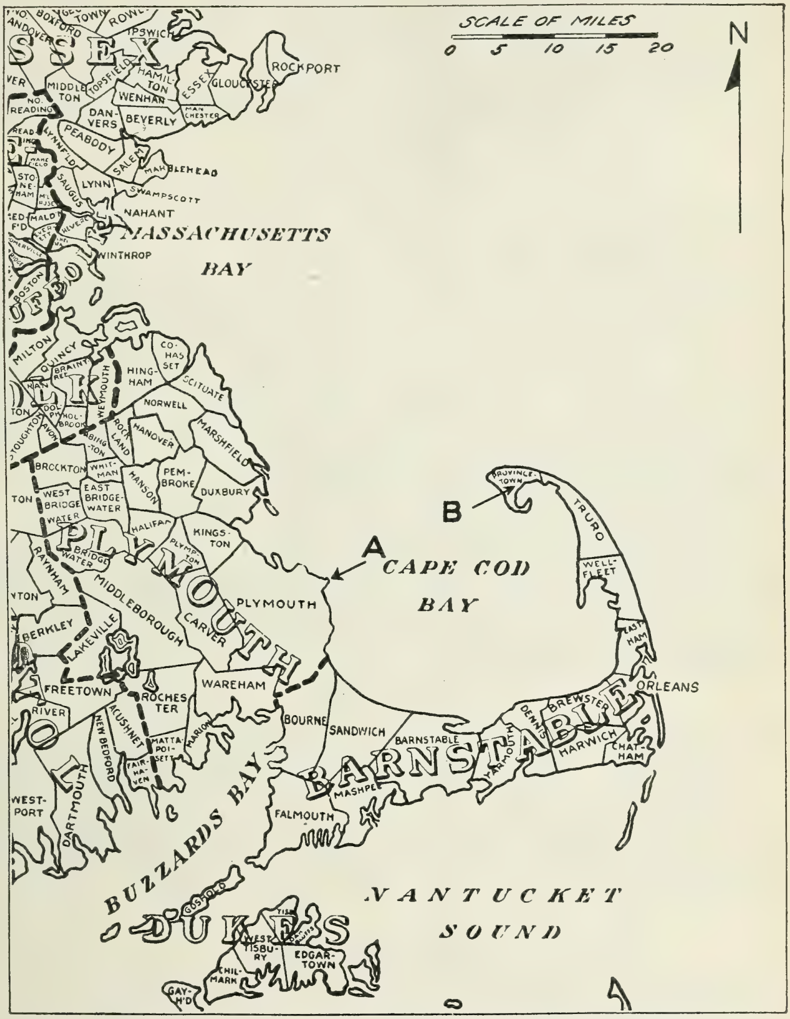
SCALE OF MILES
0 5 10 15 20
N
ESSEX
ROCKPORT
GLOUCESTER
IPSWICH
MIDDLETON
TOPSFIELD
HAMILTON
WENHAM
DANVERS
BEVERLY
MANCHESTER
PEABODY
SALEM
MARBLEHEAD
LYNN
SWAMPSCOTT
NAHANT
SAUGUS
WINTHROP
BOSTON
MASSACHUSETTS BAY
SUFFOLK
MILTON
QUINCY
BRAINTREE
WEYMOUTH
HINGHAM
COHASSET
SCITUATE
NORWELL
NORFOLK
HOLBROOK
AVON
STOUGHTON
ROCKLAND
HANOVER
MARSHFIELD
ABINGTON
BROCKTON
WHITMAN
PEMBROKE
HANSON
DUXBURY
WEST BRIDGEWATER
EAST BRIDGEWATER
HALIFAX
KINGSTON
PLYMPTON
PLYMOUTH
BRIDGEWATER
RAYNHAM
MIDDLEBOROUGH
CARVER
BERKLEY
LAKEVILLE
FREETOWN
ROCHESTER
WAREHAM
FALL RIVER
ACUSHNET
NEW BEDFORD
MATTAPOISETT
MARION
FAIRHAVEN
DARTMOUTH
WESTPORT
BRISTOL
BUZZARDS BAY
BOURNE
SANDWICH
BARNSTABLE
FALMOUTH
MASHPEE
YARMOUTH
DENNIS
BREWSTER
HARWICH
CHATHAM
ORLEANS
EASTHAM
WELLFLEET
TRURO
PROVINCETOWN
A
B
CAPE COD BAY
NANTUCKET SOUND
DUKES
GOSNOLD
WEST TISBURY
TISBURY
EDGARTOWN
CHILMARK
GAY HEAD

FIG. 47.—Map showing scene of flight experiment across Cape Cod Bay in 1922. A, liberation point. B, recovery point

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[11] See footnote 1.

PHOTOTROPISM

Repeated observations in New England with various types and colors of lights have failed to show that *Pyrausta nubilalis* moths were attracted to artificial lights to any extent, even though these observations were carried on in fields where the moths were very numerous and during their seasonal period of greatest activity. Gasoline and kerosene lanterns, acetylene lights, and electric lights of white, yellow, blue, green, red, and violet were used in these experiments. During June, 1920, a gasoline trap lantern was suspended 8 feet above the ground and run for 20 consecutive nights in a cornfield at Watertown, Mass., where hundreds of these moths were in flight. During this period 87 moths were captured, consisting of 57 males and 30 females. This result was typical of similar experiments in which were used kerosene trap lanterns with yellow, white, blue, green, and red colored globes at distances of from 2 to 8 feet above the ground. Practically the same results were obtained with uncolored acetylene lights and with electric lights of white, yellow, blue, green, red, and violet. Three 100-candlepower nitrogen bulbs were used in each of the electric trap lights. Judging from the comparative number of moths captured at the different colored lights a slight preference was shown for white and yellow lights. The proportion of males captured usually was greater than that of the females. Most of the latter were gravid.

Little difference was noted between the comparative attractiveness of moving and stationary white lights.

Jablonowski[12] records an observation by L. Baross, of Bankut, Hungary, in which 80 per cent of the total Lepidoptera captured at acetylene trap lights during the period from June 24 to July 7, 1904, were *P. nubilalis* moths. The exact number of moths captured and the proportion of sexes were not recorded.

CHEMOTROPISM

The moths were not attracted to various sirups, fresh or decaying fruit, honey, stale near beer, or to various aromatic oils. These baits were placed in wire-screen cylinders and inclosed in Shaw moth traps, the sides of which were coated with sticky tree-banding material in such a manner that any moths attracted to the bait would be captured. The traps were suspended in cornfields where the moths were numerous, but with negative results.

SEXUAL ATTRACTION

Although it is apparent that the attraction between the sexes of *Pyrausta nubilalis* must be highly developed, the phenomenon of assembly does not appear to be as pronounced as that exhibited by many other Lepidoptera. Only occasional males were attracted, at any hour during the day or night, to large screened inclosures in the laboratory yard at Arlington, Mass., where several hundred females were emerging daily, although large numbers of males were present in the immediate vicinity. In field tests seven wire-screen assembly cages containing newly emerged virgin females were erected in fields where the moths were numerous. Fresh virgin females were placed in the cages at intervals of two or three days and the older ones removed. These cages were in operation for an average period of 18 days, and during that period an average of only five males per cage were caught in the coating of sticky tree-banding material with which the surfaces of the cage and its support were covered, although large numbers of males were observed in the immediate vicinity. Most of the captured males were attracted to these cages within 24 hours after fresh females were added. During the progress of the flight experiments discussed in preceding paragraphs an attempt was made to recover the stained males by employing a similar cage but with negative results.

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[12] See footnote 1.

DISPERSION

The principal factor contributing to the long-distance dispersion of *Pyrausta nubilalis* is the transportation of infested plant products or plant remnants. After the insect becomes established in an area local dispersion also occurs by means of flight or carriage of the moths, and in some instances through the drift of infested plant material in water.

ARTIFICIAL DISPERSION

Mention has previously been made of the probability that the European corn borer originally gained entrance to North America in shipments of raw broomcorn (fig. 2) from Italy and Hungary; a probability that was apparently confirmed when commercial shipments of this material, received at the port of New York during February and March, 1920, in April, 1922, and again in March, 1923, were found by inspectors of the Federal Horticultural Board to be infested by *P. nubilalis* larvae. This occurrence illustrates the ease with which the insect may be transported for great distances, especially during its larval period; and from what has already been stated concerning the ability of the larvae successfully to complete their development under adverse circumstances, it is apparent that at least a small percentage of the individuals contained in such material may transform to adults and start new infestations, provided they are able to gain access to any of their many host plants.

The great variety of plants infested by the insect, and its habits with relation to these plants, also contribute to the danger of dispersion by common carrier. This danger is especially pronounced in the instance of the shipment of infested ears of sweet corn in the roasting-ear stage, corn on the cob, cornstalks used as packing material or otherwise, broomcorn (including all parts of the stalk), the stalks of all sorghums, and Sudan grass. In New England the plant products likely to be infested during certain periods of the year and which commonly enter commerce include, in addition to the above, celery, green beans in the pod, beets with tops, spinach, rhubarb, oat and rye straw as such or when used as packing material; also cut flowers or entire plants of chrysanthemum, aster, cosmos, zinnia, hollyhock, gladiolus, and dahlia. In some instances larvæ or pupæ have been found in the cracks and crevices of boxes or other containers which had been used in shipping infested vegetables. These containers are permanent equipment of farmers and produce dealers, and are used in turn for shipping a great variety of vegetable products. Unless carefully inspected, they may serve as a means of dispersing the insect.

Quarantine restrictions are now in force prohibiting the transportation of the above products, or their containers, outside the limits of areas known to be infested, except when duly inspected and found to be free of infestation by the European corn borer. The activities in connection with the quarantine will be discussed in a separate publication.

TRANSPORTATION OF ADULTS

No direct evidence has been obtained relative to the transportation of the moths on trains, autos, and other vehicles, but it is believed that this factor may contribute to the dispersion of the insect. In the New England area the waste places adjacent to railroad yards are commonly overgrown with favorite weed hosts of the insect, and in some instances such weed areas are very heavily infested. It is possible that the moths which habitually seek protection from the direct sunlight might alight upon cars standing upon these tracks and later be carried to distant points. There is the same danger, though perhaps to a lesser degree, when autos and other vehicles halt along the roads adjacent to infested cornfields and weed areas. In experimental tests wherein moths were liberated inside an auto during the early evening, two moths which alighted upon the outside of the machine remained in this position until the auto had traveled distances of 3 and 5 miles, respectively, from the starting point. Under similar conditions two moths which alighted upon the inside of the auto remained in this position until 12 and 19 miles, respectively, had been covered.

GARBAGE

During the summer and early fall the kitchen garbage from hotels, restaurants, private homes, and the like may contain living larvæ or pupæ in ears or cobs of sweet corn, or portions thereof, which have been discarded after purchase on account of the presence of the insect. Larvæ are also frequently present in the husks, silk, undeveloped tips and ear stems. These portions are commonly removed from sweet-corn ears before cooking and thrown into the swill container. Other plant material which frequently harbors the insect and which is commonly discarded during preparation for the table include the outer stalks of celery, and injured portions of beet tops, rhubarb, Swiss chard, spinach, and string beans. Garbage of this character may act as a vehicle for the insect, as it is frequently transported considerable distances for use as food for pigs or disposal otherwise. Under these conditions the larvæ may escape en route, or before the garbage is disposed of. Corncobs which have been thrown into pigpens, and subsequently removed when cleaning out the pens, have been found to contain living larvæ. Garbage is sometimes thrown into streams or bodies of water which may carry such material long distances through the influences of currents, wind, or tide.

Collections of garbage made during the summer, fall, and spring very frequently contain quantities of infested material consisting of cornstalks, and the remnants of other crops, flowering plants, weeds, and similar plant material which have been collected during the process of cleaning up kitchen gardens. This material is usually hauled to a public dump, and unless promptly burned or otherwise destroyed becomes a source of infestation to the surrounding territory. Sometimes this material is dumped along the edges of flood levels of streams or bodies of water, with the consequent danger of its dispersion. Infested cornstalks and other plant material containing living larvae have been found distributed along the beaches of New England and also upon the shores of an island several miles from the mainland. Infested material of this kind has also been found distributed along the shore of Lake Erie on the Canadian side.

WASTE PRODUCTS

The refuse from canning factories using sweet corn from infested fields commonly contains large numbers of living larvæ or pupæ. This refuse usually consists of the cobs, husks, silk, ear stems, and ears on which the kernels are not properly developed, or which are affected by insects or plant diseases. Most of this infested material is hauled away by farmers, often to points outside the infested area, and fed to livestock or used as fertilizer. Under these conditions an opportunity is afforded for any borers contained within the materials to escape en route, and others may escape after reaching the farm (fig. 48), thus starting new infestations.

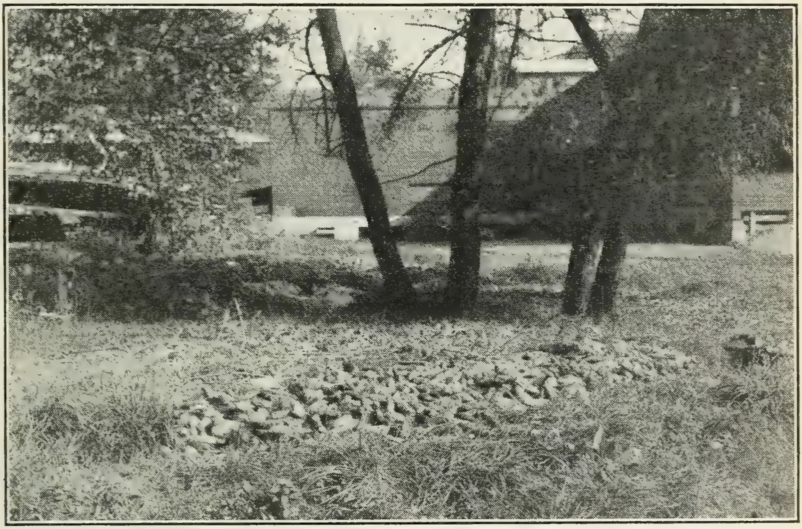

FIG. 48.—Waste from canning factory dumped at edge of field. Many of these sweet-corn cobs were infested. They should be collected when dry and burned. Silver Creek, N. Y., September, 1920

Reference has previously been made to the danger of dispersing the insect in refuse from broom factories. During the process of manufacturing brooms, sections several inches long are usually removed from the butts and discarded. The European corn borer has been found commonly in that portion of the plant comprising the butt in broomcorn grown in Massachusetts and also in the butts of raw broomcorn imported from Italy and Hungary. This refuse may become a source of danger, especially when dumped along the banks of water courses. The original infestation along the Mohawk River in eastern New York is supposed to be directly traceable to infested refuse from a broom factory at Amsterdam.

NATURAL DISPERSION

FLIGHT OF ADULTS

From what has been stated concerning the flight and oviposition habits of the moths, together with their long period of life, it is evident that dispersion by flight is an important factor. It has been shown that the moths of both sexes are possessed of strong powers of flight and that they have been observed making single flights of nearly 300 yards. The duration of adult life as shown in Table 24 averages approximately between 14 and 20 days for both sexes, thus giving the moths ample opportunity for wide dispersion in a series of flights, even if each flight was of short duration. In experimental tests individual moths of both sexes were recovered at a maximum distance of 5 miles on land and 20 miles by water from the point of liberation in the direction of the prevailing wind, indicating that they are able to disperse to at least this distance and probably for greater distances under favorable conditions. The duration of the oviposition period of the females in New England as shown in Table 24 averages approximately between 10 and 14 days, and by reference to Table 38 and the discussion concerning the daily rate of oviposition it is seen that the egg clusters are well distributed throughout the oviposition period. This affords an opportunity for the females to deposit eggs at practically any point to which they may disperse.

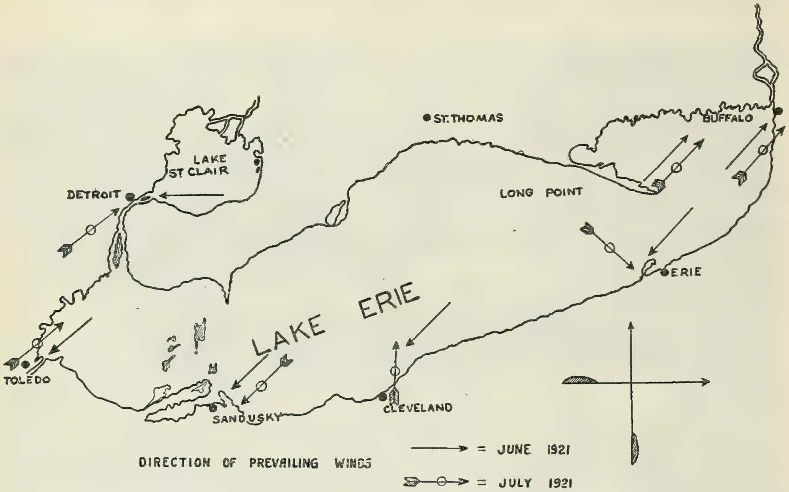

FIG. 49.—Map of Lake Erie, showing direction of prevailing winds at principal lake ports, from Weather Bureau records, during June and July, 1921. Arrows fly with the wind

In New England, and to a more limited extent in the eastern and western New York areas of infestation, the dispersion has been greatest in a general northerly direction. It appears that this direction of dispersion may have been influenced by the fact that during the flight period of the moths the prevailing winds are from the southwest. The transportation of infested plant products or plant remnants and the drift of infested material by water must also be considered as probably affecting the direction of dispersion.

The flight of moths from the older and much more heavily infested area in Ontario is believed to be the most plausible explanation of the origin of the infestation along the shore of Lake Erie in Michigan, Ohio, and Pennsylvania, and on the islands in the western end of the lake, although no conclusive evidence of this method of introduction has been established. The possibility that this infestation originated from the drift of infested plant material in the waters of the lake or from the shipment of infested plant products must also be considered. A study of the available wind records of the Lake Erie weather stations for the period 1916 to 1921 showed that during the flight period of *Pyrausta nubilalis* the prevailing winds were from the southwest, which fact would apparently prevent the possibility of the moths flying toward the southern or western shore of Lake Erie, but on certain days of that period, particularly during 1921, when infestation was first found in the American areas in question, the directions of the winds and of occasional summer gales were from points north (fig. 49), which would aid the moths in any flight toward the American side. According to Crawford and Spencer (72) the flight period of the moths in Ontario extended from approximately June 16 to July 25 in 1921. During this period the prevailing winds, particularly during June, blew directly from southern Ontario toward the southern and western shores of the lake. (See map, fig. 1.) Although the direction of the prevailing winds during July, 1921, was from the southwest at most of the lake stations where wind records were available, at Erie, Pa., the prevaling winds were from the northwest, or from the direction of the infested areas of Ontario. Moreover, there were gales from the northwest at some of the other southern and western lake stations during this month, as shown in Table 40.

It is apparent from the information shown in Table 40 that there was an unusual amount of wind movement from the north and east during June and July, 1921, as compared with previous years. The fact that the original infestation in Ohio and Michigan was confined to the islands and the townships bordering the lake, and that this infestation followed an unusual amount of wind movement from the direction of the infested areas in Ontario, would appear to indicate the probability of wind spread from Ontario as the causative agent.

TABLE 40.—*Direction and velocity of wind movement in Lake Erie region during June and July, 1916 to 1921, inclusive*

Locality	Year	June				July			
		Prevailing wind direction	Gales (maximum velocity)			Prevailing wind direction	Gales (maximum velocity)		
			Velocity	Direction	Date		Velocity	Direction	Date
			Miles per hour				*Miles per hour*		
Long Point, Ont	1916	SW.	37	SW.	2	SW.	31	W.	31
			36	E.	6	--------	--------	--------	--------
			32	E.	7	--------	--------	--------	--------
	1917	SW.	37	SW.	3	SW.	35	SW.	1
			34	SW.	29	--------	33	SW.	29
	1918	NW.	41	SW.	11	SW.	37	NW.	1
			32	NW.	12	--------	--------	--------	--------
			37	S.	21	--------	--------	--------	--------
			32	N.	23	--------	--------	--------	--------
	1919	NE.	33	NE.	28	SW.	33	SW.	10
			--------	--------	--------	--------	32	NW.	23
	1920	SW.	30	N.	5	SW.	30	SW.	23
			31	NE.	17	--------	--------	--------	--------
			37	SW.	21	--------	--------	--------	--------
	1921	SW.	31	NE.	1	SW.	None.	--------	--------
Buffalo, N. Y	1916	SW.	58	SW.	9	SW.	42	SW.	2
	1917	SW.	68	SW.	13	SW.	72	NW.	9
	1918	SW.	60	NW.	11	SW.	60	SW.	1
	1919	SW.	37	SW.	5	SW.	47	SW.	10
	1920	SW.	56	W.	29	SW.	56	W.	23
	1921	SW.	46	SW.	11	SW.	44	SW.	28
Erie, Pa. (169 feet)[1]	1916	SE.	52	SW.	24	S.	43	W.	8
	1917	SW.	46	SW.	3	SW.	44	SW.	13
	1918	S.	42	SW.	11	S.	42	W.	1
	1919	NE.	34	NE.	28	NE.	46	W.	10
	1920	W.	41	W.	21	NW.	43	W.	18
	1921	NE.	37	W.	13	NW.	36	S.	27
Cleveland, Ohio	1916	S.	39	W.	16	NE.	44	NW.	2
	1917	SW.	58	NW.	23	S.	36	N.	27
	1918	NE.	43	W.	12	NE.	48	NW.	1
	1919	NE.	39	NE.	28	NE.	36	N.	15
	1920	SW.	53	W.	16	SW.	44	N.	18
	1921	NE.	35	NE.	4	S.	46	NW.	14
Sandusky, Ohio	1916	SW.	38	W.	2	E.	39	NW.	20
	1917	SW.	38	NW.	19	SW.	34	E.	21
	1918	SW.	40	W.	30	NE.	46	NW.	29
	1919	W.	26	NE.	21	NE.	42	NW.	9
	1920	SW.	38	NE.	17	SW.	33	NE.	25
	1921	NE.	35	NE.	3	SW.	42	W.	30
Toledo, Ohio (243 feet)[1]	1916	SW.	45	SW.	2	NE.	48	NW.	20
	1917	SW.	48	SW.	7	SW.	41	SW.	1
	1918	SW.	44	SW.	1	W.	40	W.	1
	1919	SW.	45	SW.	19	SW.	47	NW.	9
	1920	SW.	38	W.	21	SW.	44	SW.	8
	1921	NE.	39	W.	27	SW.	56	NW.	29
Detroit, Mich. (256 feet)[1]	1916	S.	37	W.	2	(2)	--------	--------	--------
	1917	SW.	46	W.	2	(2)	--------	--------	--------
	1918	E.	44	W.	1	(2)	--------	--------	--------
	1919	E.	38	N.	20	(2)	--------	--------	--------
	1920	W.	35	SW.	28	(2)	--------	--------	--------
	1921	E.	40	NW.	27	SW.	56	SW.	27

[1] Elevation of anemometer. [2] No data.

THE WATER-DRIFT THEORY OF DISPERSION[13]

The water-drift theory in the dispersion of the European corn-borer has resulted from attempts to explain the spread of this insect in the Lake region of the United States during the years 1919, 1920, and 1921 and about the shores of Lake Ontario during subsequent years. This theory, although difficult to prove, must be considered together with the flight-of-moths theory of dispersion about these

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[13] Prepared by Geo. W. Barber, assistant entomologist.

Lakes, because either one or both of these methods of dispersion may have been in a large measure responsible for this spread, and each may have a very important bearing on the future dispersion of this insect in the United States.

The spread of this insect in the Lake region of the United States, which is believed to have had as a center the large infestation in south-central Ontario, Canada, was found by scouting records to have been as follows: The earliest discovered infestation in this area was a section southwest of Buffalo, N. Y., embracing 13 townships, and the township of Girard, Pa., found to be infested in 1919. In 1920 13 additional townships in the vicinity of the larger infestation near Buffalo were added, and during the same season a large infestation was found in south-central Ontario, bordering Lake Erie, together with a small strip bordering the lake just west of Buffalo (fig. 50). In 1921 a most important infestation was found comprising a narrow strip of territory almost completely surrounding the southern shore of Lake Erie and including the islands situated near Sandusky, Ohio. The spread of the insect in this area since 1921 has been largely an advance inland from the southern shore of Lake Erie, a great spread northward in eastern Michigan, and a spread to the shores of the western half of Lake Ontario (fig. 1).

If there is any possibility in the water-drift theory, it is important that it should be discussed at the present time (1924) when the spread of the insect in Ohio has in some localities already crossed the crest of the watershed toward the south. In this direction lie great chains of rivers, large and small, emptying into the Ohio River, and it, joining the Mississippi, opens up the great valleys of these waterways, containing some of the richest, most valuable, and important agricultural lands in this country, to possible infestation by this dangerous insect. It is not difficult to picture infested cornstalks being carried, first into the smaller streams by means of the spring thaws, thence into larger streams, eventually into the Ohio or the Mississippi, and finally being cast on the bank of one of these rivers, possibly hundreds of miles from the place of origin, there to dry in the spring sunshine, the insect developing, finding food plentiful, multiplying, and perhaps eventually causing a large and important infestation before being discovered, too late to undertake measures for complete eradication.

At present there seem to be five important points where water drift in relation to dispersion in the near future may prove of great importance: (1) Through the tributaries and head waters of the Ohio to the great river valleys already mentioned; (2) through the Michigan streams flowing into Lake Michigan, thence to the shores of Wisconsin and Illinois; (3) from Lake Erie or Lake Ontario into the St. Lawrence; (4) from the isolated infestation about Albany, N. Y., down the Hudson, and not only menacing the banks of the Hudson, but also threatening the shore of New Jersey, should infested material be finally thrown into the ocean; and (5) in New England, where the infestation in Massachusetts and New Hampshire is spreading toward the Connecticut Valley, cornstalks may be carried down the Connecticut River, endangering the lower Connecticut Valley, in Massachusetts and Connecticut, an important farming section.

A further reason for apprehension concerning the possibilities of this means of spread lies in the increase in the intensity of the infestation at the probable centers from which such spread may proceed. If there is only a light infestation at these points—for example, if cornstalks average only one individual per stalk—the element of chance may result in drifting stalks being cast on shore singly. The ability of the individual from such a cornstalk to produce progeny will naturally depend upon whether an individual of the opposite sex is to be found. When the infestation at the center of the spread is of more than a single larva per stalk, a new infestation may result from a single cornstalk thrown on shore, since the larvae it contains may result in several adults of each sex. While in the first instance the carrying of cornstalks by water drift may rarely result in new infestations or in infestations only in localities where several stalks have been thrown on shore together, in the second case infestations are much more likely to result. Furthermore, in the case of cornstalks being carried long distances by water, many of the larvae contained in such stalks may perish before the stalks are cast on shore, but in this case the chance of larval survival and resulting infestation is increased in proportion to the rate of the infestation of such cornstalks.

Another reason for apprehension as the infestations increase in intensity lies in the breakage of cornstalks because of the feeding of larvae of this insect. Heavily infested stalks break over much more easily than stalks containing only a few larvae, and for this reason they would be much more likely to be swept away by rains or floods in the spring.

A case illustrative of this condition may be mentioned in regard to the isolated infestation of the insect in eastern New York around Albany. The question has been asked, if water drift is an important means of dispersion, why has no infestation appeared along the lower Hudson to indicate a distribution of this sort from the Albany area? There are two facts that may be offered in reply: (1) The infestation in the Albany area has never been heavy as compared with New England infestations, so that the conditions favorable to the establishment of a new colony, as described in the two proceding paragraphs, may not have obtained; (2) the discovery of a new infestation, when individuals are few and scattered, is by no means a simple matter, and although repeated and careful scouting has failed to bring to light any infestations indicative of water spread along the Hudson, this is not necessarily proof that such infestations may not eventually be found.

Because it is necessary to face this danger if it exists, the arguments that seem to support the water-drift theory in the dispersion of the insect about Lake Erie are presented, together with remarks on the infestation in New England. What factors caused the distribution of the insect about Lake Erie are now of minor importance, since the infestation is already general, but it is important that the evidence be examined to the end that if it is possible a repetition of this occurrence may be prevented.

The discovery during 1921 that a narrow band of infested territory (fig. 50) practically surrounded Lake Erie on the American side was rather remarkable. Although the discovery of the infestation during that year was not proof that such infestation had originated during that or the preceding year, the evidence indicated that the infestation was not of long standing and had probably originated during 1921.

It is very difficult to obtain exact information on the flight habits of the adults of this insect, especially because natural flight occurs at night, and what is now known concerning the detailed habits of flight has been obtained during the hours of daylight when flight of the insects is possibly somewhat abnormal. One theory concerning air currents that pass over a body of water is that they tend to drop objects that they are carrying on reaching land. This theory would help to explain the regularity in which early infestations on the southern shore of Lake Erie followed the shore line, had air currents or winds played an important part in this distribution of the insect. But even if this were true, the possibility that water drift was of equal importance in dispersion about the lake still exists.

Certain of the factors that support the water-drift theory of distribution of this insect about Lake Erie may now be considered.

The New England Infestation

The New England infestation is fairly illustrative of the possible spread of the insect by water drift, particularly as applied to Cape Cod. The early infestation on Cape Cod was principally on the northern shore, or that joining Massachusetts Bay, facing the original New England infestation of this insect, as it has been conceived, and where the most severe infestation is found to-day. Had water drift played no part in this infestation, it seems remarkable that the infestation should develop in this way. The northern shore is a much poorer agricultural section than is the southern part of Cape Cod, yet in the southern part the infestation has been slow in developing and is of much less intensity. The infestation here, then, has developed in the way that would be expected, had water drift played an important part in dispersion. Had flight of moths played an important part in this spread, it seems improbable that so large a proportion of them would have been able to descend so soon after reaching land, but that many would have been carried either farther inland on the cape, or completely over it, and thence out to sea. In this connection it may be remarked that the distance that the moths would have been carried by such winds would have been somewhat less than half the distance from the probable original seat of infestation across Lake Erie. The shipment of infested vegetables to summer resorts as a means of dispersion of the insect is often mentioned in this case, but although this factor has undoubtedly been of importance, it must be said that the large summer resorts on Cape Cod are on the south shore, whereas the important infestation of the insect has been found on the north shore. That infested cornstalks do float out into Massachusetts Bay has been proved by several examinations of the islands in Boston Harbor. In 1920 a thorough examination of one of the larger of these islands (Inner Brewster Island) showed that the only infestation on the island at that time was in a single plant of cocklebur which contained several larvae. This plant was growing on an arm of the island extending toward the mainland, and on which considerable quantities of refuse had been thrown by the sea. The following year a second examination of the island showed that the only larvæ then present were contained in a piece of drifted cornstalk that, together with a considerable quantity of refuse, had been cast on the island, curiously enough, in nearly the exact spot on which the infested cocklebur had been found the preceding year. This island is situated about a mile from the nearest mainland, so that this cornstalk may have been carried by the water for this short distance or for a much greater distance, it being impossible to determine the exact spot of its origin. This case, however, is very suggestive when the infestation in New England is studied and it is seen how closely the oldest and most important infestation of this insect follows the shore line.

The Flight Habits of Moths

The adults of this insect are strong flyers, active at night and resting during the day on the underside of leaves of plants or in other sheltered places. They are not easily dislodged by winds, being able to cling tightly to the leaves that offer them protection. Experiments at the seashore have shown that they are unable to make headway against a wind of from 20 to 30 miles an hour, although contesting the force of the wind as best they can.

So little is known concerning the cause of natural migration of night-flying insects that it is impossible to say whether this phenomenon has entered into the problem under discussion. However, a natural migration of adults might be more probable in areas of dense population of the insect than in areas only moderately infested.

Habits of Larvae in Regard to Water

In order to prove that distribution of the larvæ of this insect is possible by means of water drift, it is necessary to know that larvæ are able to survive after cornstalks have floated in water for a considerable period. In winter and early spring, when the larvæ are in a dormant condition, it is known that they survive after stalks have floated for a few weeks or have even been submerged. In fact larvæ in experiments have been known to pupate in floating cornstalks. Table 41 gives some results of the survival of larvæ in infested cornstalks that remained in water for protracted periods during the winter of 1921–22. In this case the stalks floated until the surface of the water was frozen, holding them in ice for some time, and in the spring they were submerged after the ice melted.

Table 41.—*Survival of larvæ of Pyrausta nubilalis in cornstalks placed in water*

Date placed in water	Kind of water	Date of recovery	Total number of larvæ	Number that survived
Dec. 3, 1921	Salt	Apr. 10, 1922	150	1
Dec. 3, 1921	do	Mar. 4, 1922	146	17
Dec. 2, 1921	Fresh	Mar. 21, 1922	141	0
Dec. 2, 1921	do	Apr. 10, 1922	122	10
Nov. 22, 1921	do	Feb. 14, 1922	90	1

Other experiments of this sort have been conducted with varying results, the following being one of the most interesting.

On February 7, 1921, a number of cornstalks and stubble containing overwintering larvae of this insect were placed in a burlap bag, weighted down with stones, and thrown into a small brook in Arlington, Mass. This bag was recovered on March 7, and of a total of 166 larvae that these stalks contained 81 were found to be alive, 73 dead, and 12 were injured in examination of the stalks. The live larvae were kept in a cage for observation of future development and 67 pupated, from which 33 moths emerged, 13 being females, all of which deposited eggs. There seems no question, therefore, but that larvae contained in cornstalks carried into a body of water and thrown on land again within a reasonable period of time may survive in numbers sufficient to cause an infestation of the insect in the new locality.

THE WATER CURRENTS OF LAKE ERIE

In Figure 50 the direction of the water currents of Lake Erie are shown, together with the Canadian infestation found in 1920, the infestation in New York and Pennsylvania found in 1919, and the infestation on the United States side of this lake in 1921. It may be seen that drift carried into the lake on the Canadian side may first be carried somewhat toward the west until it meets counter-currents, when it may travel around and between the group of islands located off Sandusky, Ohio, and finally, meeting the main current of the lake, may be deposited at almost any point on the southern shore of the lake. The infestation found in 1921 very closely coincides with this movement of the water of the lake. There is the further possibility that infested stalks were carried into Lake Huron from the western watershed in Ontario and thence to the Michigan shore, or eventually to Lake Erie and thence cast on shore.

If the large infestation discovered in south-central Ontario in 1920 is accepted as the source of all the spread of this insect in the lake region of America, and if water drift of infested cornstalks from this Canadian area played an important part in this dispersion of the insect, the heaviest infestation resulting from such dispersion might be expected at the points where the greatest number of stalks would be likely to be thrown on shore. The water currents of Lake Erie show that such a point would be the shore line of the lake between Buffalo and Dunkirk, N. Y. (fig. 50), and it is an exceedingly interesting, not to say curious, coincidence that this is in fact the point on the southern shore of the lake that was originally found to be most severely infested.

Although considerable scouting has been done along the southern shore of Lake Erie, no cornstalks have been found that might have been thrown on shore by the waters of the lake except those traceable to American origin. Although the inability to find such material in the localities and on the dates when such work was done may be advanced as proof of the flight theory of dispersion, a careful examination of the entire southern shore line of hundreds of miles is a difficult project in which bits of cornstalks may be easily overlooked. Furthermore, great numbers of cornstalks may be cast on the southern shore of Lake Erie only during certain years when particularly favorable conditions occur, in which case extensive unsuccessful scouting along the shore during certain years when such favorable conditions for much water drift did not obtain, would not prove that during a previous year, more favorable to this phenomenon, such conditions did not exist. In other words, extensive

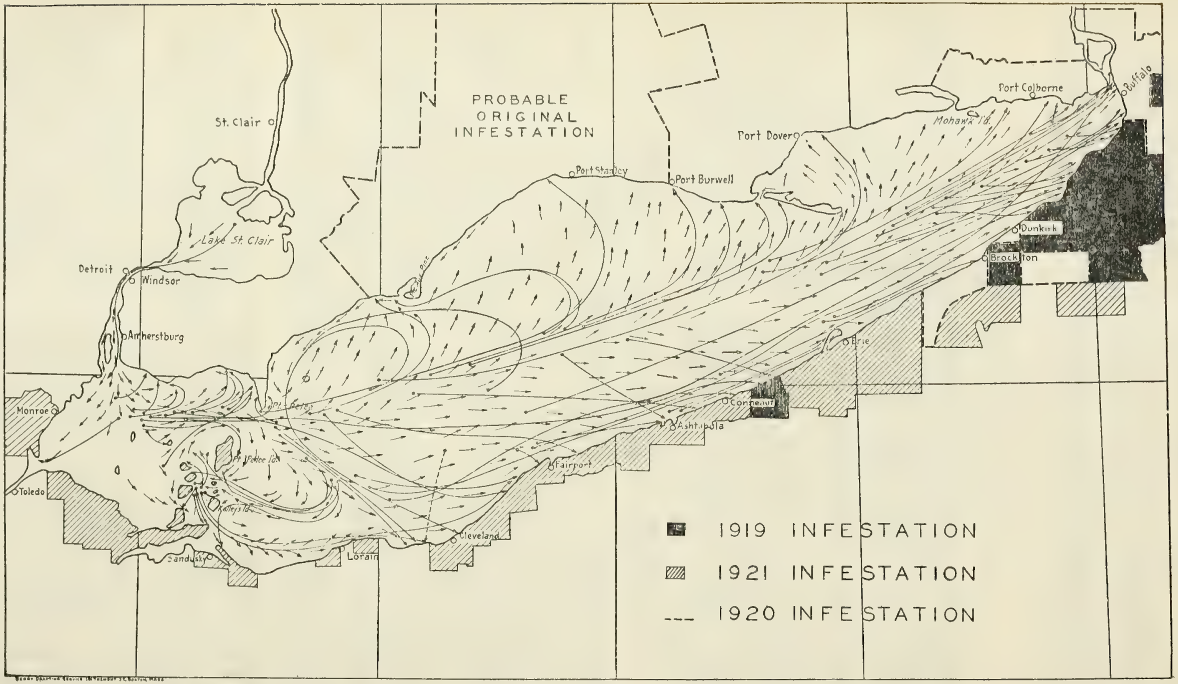
PROBABLE ORIGINAL INFESTATION
St. Clair
Lake St. Clair
Detroit
Windsor
Amherstburg
Monroe
Toledo
Sandusky
Kelleys Id.
Pt. Pelee Id.
Pt. Pelee
Lorain
Cleveland
Fairport
Ashtabula
Conneaut
Erie
Brockton
Dunkirk
Buffalo
Port Colborne
Mohawk Id.
Port Dover
Port Burwell
Port Stanley
1919 INFESTATION
1921 INFESTATION
1920 INFESTATION

FIG. 50.—Lake Erie and adjacent territory; showing water currents of the lake (arrows) and bottle-paper courses of 1892, 1893, and 1894 (lines), redrawn from map by Weather Bureau. The black area shows the infestation of the European corn borer, discovered in 1919; the area inclosed by a broken line shows the infestation discovered in 1920, including the probable original infestation in Ontario, Canada; the shaded area shows the additional infestation discovered in 1921

water dispersion may not be an annual occurrence, but may vary considerably from year to year, depending on a number of natural factors.

THE WATER CURRENTS OF LAKE ONTARIO

The water currents of Lake Ontario (fig. 51) are suggestive of the possible means of spread of the insect to the territory about this lake now known to be infested. Here the infestation on both the northern and southern shores has been found to be spreading more rapidly along the shores of the lake. The water currents indicate that if water drift of infested cornstalks does play an important part in the dispersion of the insect, their direction is such as to carry infested cornstalks to all the shores of the lake, as well as to carry them into the St. Lawrence River, thus opening up a large area to possible infestation by this insect.

DISPERSION IN RELATION TO THE SEASON

The period of maximum flight of adults in the area about Lake Erie extends over a period of two or three weeks in July and early August, so that dispersion by flight must take place within this short period. Larvae becoming full grown by late August or September remain in the host plant until the following June, and during most of this time they are inactive. Over all this period, therefore, dispersion by the movement of infested stalks may take place, and from November to April the disposition of the stalks would be attended by little movement of larvae since they are in a dormant condition.

THE NATURAL PHENOMENA OF SPRING

The melting of snow in the spring and the breaking up of ice usually result in a swelling of streams and rivers, an increase in the rapidity of flow in many of them, and the distribution of débris that has been brought to them by the melting snow and ice. There are, then, two ways in which infested cornstalks may be distributed by water: (1) By floating free cornstalks, which may take place at any time during the fall, winter, or spring, and (2) by the distribution of cornstalks frozen in blocks of ice, which takes place mainly during the general thaws in the spring. In connection with this point, a note by Crawford (*1*) may be highly suggestive. He states that on April 4, 1923, "Considerable quantities of cornstalks were found to have been carried into Lake Erie by water from the spring floods. Material was also found frozen in the dislodged ice. This ice was later blown out into the the lake by the winds from the north, suggesting a probable means of infesting the southern shore of Lake Erie." The same authority has reported the finding of a submerged infested cornstalk at a point in Lake Erie 17 miles from Port Stanley, Ontario. In this case, although there was considerable scouting on the southern shore of Lake Erie in the spring of 1923, no cornstalks were found to have been cast on shore, so that it appeared that this material had not reached the southern shore of the lake that year.

In many cases it is probable that the insects may be more successfully transported by cornstalks frozen in ice than in free stalks,

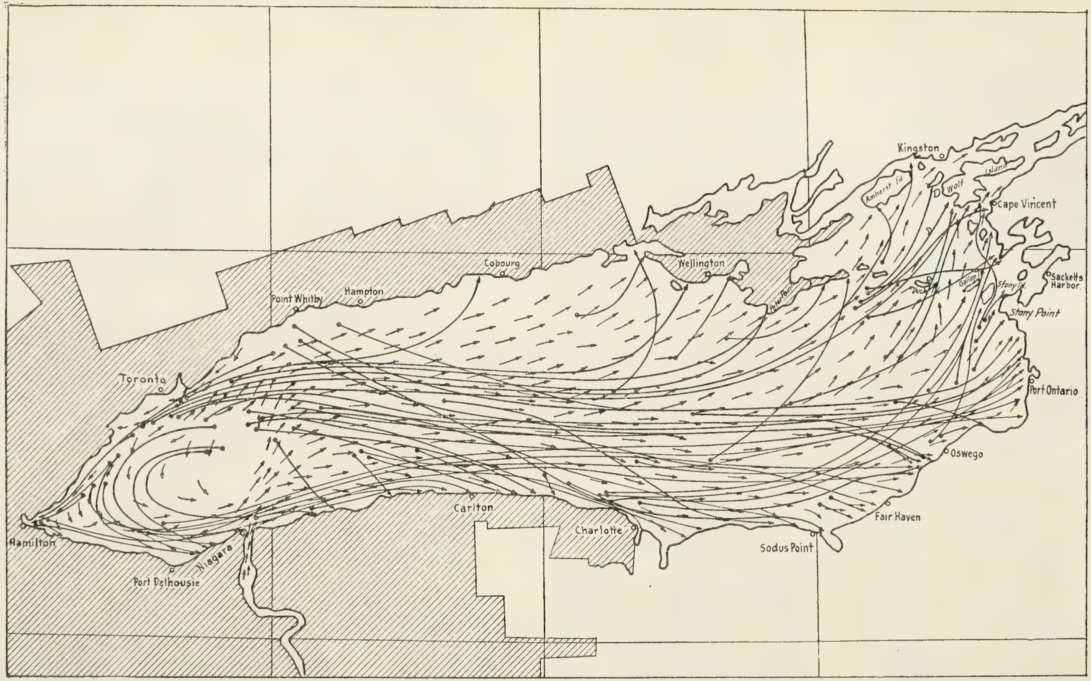
Kingston
Amherst I'd
Wolf
Island
Cape Vincent
Sacketts Harbor.
Stony I'd.
Galloo I'd
Duck I'd
Stony Point
Peter Point
Wellington
Cobourg
Hampton
Point Whitby
Toronto
Hamilton
Port Dalhousie
Niagara
Carlton
Charlotte
Sodus Point
Fair Haven
Oswego
Port Ontario

FIG. 51.—Lake Ontario and adjacent territory; showing water currents of the lake (arrows) and bottle-paper courses of 1892, 1893, and 1894 (lines), redrawn from map by Weather Bureau. The shaded area shows the known infestation of the European corn borer up to December, 1924

for if the ice melts slowly and the current bearing it is swift enough, it may be carried considerable distances before being thrown on shore or melted. Free cornstalks tend to become saturated with water and sink after a varying length of time in water, so that although great numbers of stalks may be carried into a body of water like Lake Erie, many may sink before reaching another shore, and although some of these may eventually reach shore, for example by the movement of water during storms, the possibility is that as a usual thing most of the larvae contained in such stalks perish.

Cornstalks would be more likely to be swept along in the rivers where quicker currents are found, particularly in the spring when many rivers are swollen and more active, than in large bodies of water such as lakes, where cornstalks might sink before being carried to another shore.

SURVIVAL OF LARVAE AND PUPAE IN WATER

In order to determine the survival of larvae or pupae when contained in floating or submerged plant material, a series of experiments were carried on in New England in both fresh and salt (sea) water. The reaction to water of free larvae and pupae was also investigated. The results of these experiments are shown in Table 42.

TABLE 42.—*Survival of Pyrausta nubilalis larvae and pupae in water*

Materials	Date placed in water (1920)	Date removed (1920)	Duration period	Number of specimens	Per cent alive	Remarks
			Days			
Cornstalks submerged in fresh water. Overwintering larvæ.	Feb. 7	Mar. 7	28	173	79.8	67 larvæ pupated; 33 produced moths.
Do	Mar. 9	Apr. 21	43	89	1.1	Larva died 16 days later.
Do	do	May 10	62	98	None.	
Cornstalks floating in fresh water. Overwintering larvæ.	Mar. 16	Apr. 21	36	55	3.6	1 surviving larva pupated and produced a moth.
Cornstalks floating in sea water. Overwintering larvæ.	Mar. 15	Apr. 21	37	212	1.4	3 surviving larvæ died 15, 37, and 41 days later.
Do	do	May 16	62	42	None.	
Free larvæ submerged in fresh water in wire-screen cages. Overwintering larvæ.	May 4	May 6	2	26	88.5	Majority of surviving larvæ pupated and produced moths.
	do	May 9	5	23	95.9	
	do	May 13	9	22	22.7	
	do	May 18	14	5	40	
			Hours			
Cornstalks submerged in fresh water in wire-screen cages. First-generation larvæ.	July 29	July 31	42	10	20	1 larva pupated and produced a moth.
	do	Aug. 2	96	10	None.	
	do	Aug. 3	120	10	None.	
Cornstalks submerged in sea water in wire-screen cage. First-generation larvæ.	Aug. 5	Aug. 6	18	8	(A) None.	In (B) 2 larvæ pupated in stalks. Did not produce moths. 1 larva pupated afterwards and produced a moth. No pupation in (D).
	do	Aug. 7	42	6	(B) 16.6	
	do	Aug. 8	67	6	(C) None.	
	do	Aug. 14	216	59	(D) None.	
Cornstalks floating in fresh water inclosed by screen cylinder. First-generation larvæ.	Aug. 2	Aug. 9	163	59	11.9	5 larvæ pupated in floating stalks but did not produce moths. Three surviving larvæ pupated afterwards and produced moths.
Same as above in sea water	July 31	Aug. 2	48	100	None.	
Free larvæ submerged in fresh water in wire-screen cages. First-generation larvæ.	July 28	July 29	24	10	(A) 60	In (A) 5 surviving larvæ pupated and produced moths. Same in (B).
	do	July 30	48	10	(B) 10	
	do	July 31	65	10	None.	
	do	Aug. 1	89	10	None.	

TABLE 42.—*Survival of Pyrausta nubilalis larvae and pupae in water*—Con.

Materials	Date placed in water (1920)	Date removed (1920)	Duration period	Number of specimens	Per cent alive	Remarks
			Days			
Cornstalks submerged in fresh water. Weighted down in large wire-screen cage. Second-generation larvæ.	Aug. 27	Aug. 28	24	4	100	Larvæ left stalks within 1 hour and came to top of submerged container. Surviving larvæ normal; not observed for pupation.
	--do-----	Aug. 29	48	2	50	
	--do-----	Aug. 30	72	11	None.	
Cornstalks submerged in sea water in glass cylinder. Held in place with weighted gauze. Second generation larvæ.	Sept. 15	Sept. 17	48	5	(A) 40	Larvæ (A) to (D) left stalks within 1 hour. Surviving larvæ dead 2 days later. 11 larvæ (E) dead in burrows. Surviving larvæ alive Oct. 7.
	--do-----	Sept. 18	72	5	(B) 20	
	Sept. 17	Sept. 21	96	5	(C) None.	
	--do-----	Sept. 22	120	5	(D) None.	
	Sept. 29	Oct. 2	72	20	(E) 25	
Cornstalks floating in sea water in glass cylinder. Tanglefoot at edge of water. Second-generation larvæ.	Sept. 15	Sept. 16	24	5	(A) 100	Larvæ in (A) alive Nov. 30. (B) and (C) dead 3 days later. (D) to (F) alive Nov. 30.
	--do-----	Sept. 17	48	5	(B) 40	
	--do-----	Sept. 18	72	5	(C) 10	
	--do-----	Sept. 19	96	5	None.	
	--do-----	Sept. 20	120	5	None.	
	Sept. 24	Sept. 27	72	5	(D) 80	
	Oct. 4	Oct. 7	72	11	(E) 54.5	
	Oct. 3	Oct. 8	120	14	(F) 7.1	
Free larvæ submerged in fresh water in wire-screen cages. Second-generation larvæ.	Sept. 27	Sept. 30	72	25	40	Surviving larvæ strong and vigorous. Not observed for pupation.
Cornstalks submerged in sea water in wire-screen cage. First-generation pupæ.	Aug. 6	Aug. 7	20	10	90	6 males and 3 females emerged.
	--do-----	Aug. 8	46	10	60	4 males and 2 females emerged.
	--do-----	Aug. 9	68	10	60	2 males and 4 females emerged.
	--do-----	Aug. 10	96	10	None.	
Cornstalks floating in sea water 1 week. First-generation pupæ.	Aug. 3	Aug. 10	168	30	3.3	1 female emerged.
Cornstalks floating in fresh water. First-generation pupæ.	July 26	Aug. 9	336	10	None.	
Free pupæ submerged in sea water in wire-screen cages. First-generation pupæ.	Aug. 5	Aug. 6	17	10	80	3 males and 5 females emerged.
	--do-----	Aug. 7	41	10	60	3 males and 3 females emerged.
	--do-----	Aug. 8	67	10	10	1 male emerged.
	--do-----	Aug. 9	89	10	None.	
Free pupæ submerged in fresh water in wire-screen cages. Second-generation pupæ.	June 1	June 2	24	5	None.	
	--do-----	June 3	48	5	None.	
	--do-----	June 4	72	5	None.	
	--do-----	June 5	96	5	None.	
Free pupæ floating in sea water 2 weeks. First-generation pupæ.	Aug. 7	Aug. 21	336	50	24	12 males emerged. All emergence in first 7 days.

According to the data in Table 42 the larvae of the second or overwintering generation proved to be much more resistant to drowning during their period of inactivity in the late fall, winter, and early spring than the first-generation larvae during summer or the second-generation larvae during early fall. Some of the larvae which survived prolonged exposure to water in either floating or submerged plant material eventually pupated and emerged as adults. Very little difference was noted between the comparative effects of fresh or sea water upon the larvae and pupae.

When infested cornstalks were submerged in water for 28 days during the winter, nearly 80 per cent of the overwintering larvae contained therein survived and many of such larvae eventually pupated and emerged as moths. Less than 2 per cent of the larvae survived for 43 days, however, when they were submerged under similar conditions a little later in the season. None of these pupated, although they lived for a maximum of 41 days after being taken from the water. A small percentage of overwintering larvae contained in floating cornstalks survived, and one produced a moth, after being in the water for 36 days during the spring. Of the free larvae submerged in the water for 14 days during the month of May, 40 per cent survived and eventually developed into moths. In this and in similar experiments many larvae, which appeared to be dead when taken from the water, revived after a period of several days. It was, therefore, necessary to keep all larvae used in the experiments under observation until they revived or until decomposition began. Naturally these larvae which were retained for observation could not be returned to their natural position in the stalks of plants, but were kept in screen wire cages containing sections of cornstalks. The cages were placed in an outdoor insectary. It is believed that the chances of dispersion of infested material by water is greater during the spring than at any other period. Hence the resistance of larvae to drowning in submerged or floating material at this time is especially important. In these experiments old cornstalks remained afloat in fresh water for a maximum period of 62 days in the spring, or until taken from the water. Partly matured cornstalks placed singly in fresh water during the last week in August floated for an average period of 40 days and a maximum period of 68 days before sinking. These cornstalks were partly green, as is usual with cornstalks taken from the field at this time of year. The upper portions of the stalks were dry and the lower portions were green and succulent. Bundles of cornstalks similar to those just described, placed in fresh water on September 18, floated until they were frozen in the ice just prior to December 1, a period of 73 days. Small stalks and pieces of stalks sank sooner than entire stalks bearing ears. It appears, therefore, that in the spring or fall cornstalks may float for a sufficient period to become widely dispersed.

A small percentage of first-generation or summer larvae survived and eventually developed into moths from cornstalks completely submerged in water for 42 hours. Larvae of this generation also survived and produced moths from stalks floating in water for 163 hours, or nearly 7 days. Free larvae survived and produced moths after submergence in water for 48 hours.

When cornstalks containing second-generation larvae were submerged in water during late August, certain of the larvae survived an exposure of 48 hours, whereas two weeks later they survived a similar treatment of 72 hours in submerged and also in floating cornstalks. During the first week in October certain of the larvae survived from cornstalks floating in water for 120 hours, indicating that their resistance to drowning increased with the approach of the inactive period. Free larvae of this generation survived when submerged in water for 72 hours during the last week in September.

First-generation pupae in cornstalks which had been submerged in water for 68 hours, and in cornstalks which had floated in water for one week, produced adults. Free pupae of the first generation submerged in water for 67 hours produced a single adult, and free pupae of the second generation receiving a similar treatment for 24 hours produced no adults. Free pupae of the first generation floating in sea water for two weeks produced adults during the first 7 days. Pupae in fresh water produced adults for 6 days.

NATURAL ENEMIES

Although a variety of natural enemies of the European corn borer have been recorded in this country, usually they do not attack the insect in any appreciable numbers and can not from present indications be relied upon to hold it in check.

The fact that the larvae normally feed within their hosts greatly reduces the opportunity for attack by parasitic and predacious enemies. The small larvae, however, are exposed to attack for a short time before entering the plant. This is true also for certain individuals of the larger larvae when feeding on or near the exterior of the plant, or when migrating to other parts of the same or adjacent plants, and when seeking shelter in unprotected locations.

PARASITES

NATIVE PARASITES

In New England the small chalcid *Trichogramma minutum* Riley periodically parasitizes considerable numbers of *Pyrausta nubilalis* eggs, particularly those of the second generation in the latter part of the season. Toward the end of the summer of 1919 an average of 43.5 per cent and a maximum of 75 per cent of the second-generation eggs were parasitized in 23 towns in representative parts of the area where egg collections were made. In 1921 this species destroyed an average of 30.7 per cent, and a maximum of 74 per cent of the second-generation eggs in 24 representative towns. This chalcid is apparently very variable, however, in occurrence from year to year, as in 1920 only 6.6 per cent of the second-generation eggs were parasitized in this same area. Although the parasitism of the second-generation eggs was comparatively high during these two years, less than 1 per cent of the first-generation eggs were parasitized in this same area. In the New York areas of infestation no parasites have been found in any of the eggs collected. Table 43 summarizes the results of egg collections in New England for parasitism by *T. minutum* from 1919 to 1921, inclusive.

TABLE 43.—*Parasitism of Pyrausta nubilalis eggs by Trichogramma minutum in New England, from 1919 to 1921, inclusive*

Year	First generation			Second generation		
	Number of eggs collected	Number of eggs parasitized	Per cent of parasatism	Number of eggs collected	Number of eggs parasitized	Per cent of parasitism
1919	11,384	15	0.13	28,418	12,948	45.5
1920	28,046	29	.10	53,198	3,501	6.6
1921	36,835	266	.72	79,802	23,997	30.1
Total	76,265	310	----------	161,418	40,446	----------
Average	----------	----------	.406	----------	----------	25.05

The fact that most of the parasitism by *T. minutum* is confined to the second-generation eggs, and particularly the eggs deposited during the late season, rather reduces the effectiveness of the species as a factor in preventing injury by its host.

During 1921 a special effort was made to determine the seasonal variation in the parasitism by *T. minutum* and also to obtain a more correct average of the parasitism for the entire season than had previously been obtained in 1919 and 1920 when collections were made without proper regard to seasonal variation. The plan used in 1921 called for six uniform collections of eggs of *Pyrausta nubilalis*, three of each generation, in each of the 24 towns selected. In this manner an early, medium, and late collection of eggs was made from each town during the seasonal progress of each generation, thus effectively covering all the seasonal variations that might occur in parasitism. As a result of this system the percentage of parasitism for 1921, as given in Table 44, is probably more nearly correct than the figures given for 1919 and 1920. These collections also showed very plainly the seasonal variation in parasitism. Table 44 gives results of the six collections in four typical towns in Massachusetts during 1921.

TABLE 44.—*Seasonal variation in parasitism by Trichogramma minutum in New England in 1921*

Town (Massachusetts)	First generation, per cent of parasitism			Second generation, per cent of parasitism		
	Early	Medium	Late	Early	Medium	Late
Wakefield	0	0	0	0.5	4.3	78.5
Scituate	0	0	0	3.4	15.5	90.5
Peabody	0	0	0	5.5	11.9	62.7
Danvers	1.1	0	0	2.1	7.2	13.6

A small percentage of corn-borer larvae and pupae have been destroyed in New England each year by several different species of dipterous and hymenopterous parasites. The species which have been reared from *Pyrausta nubilalis* larvae and pupae are listed below:

DIPTEROUS PARASITES

Phorocera erecta Coq.
Exorista pyste Walk.
Masicera myoidea Desv.
Exorista nigripalpis Towns.
Carcelia ochracea V. D. W.
Compsilura concinnata Meig.

HYMENOPTEROUS PARASITES

Itoplectis conquisitor Say.
Sagaritis dubitatus Cress.
Agrypon sp.
Amblyteles brevicinctor Say.
Amblyteles rubicundus Cress.
Cryptus incertus Cress.
Ephialtes aequalis Prov.
Campoplex sp.
Microbracon caulicola Gahan.
Habrobracon gelechiae Ashm.
Epiurus pterophori Ashm.
Epiurus tecumseh Vier.
Epiurus indagator Cress.
Bassus agilis Cress.
Labrorychus prismaticus Nort.
Microgaster zonaria Say.
Meteorus loxostegei Vier.

The combined parasitism by the species listed above has totaled less than 1 per cent of the larvae and pupae collected each year. The parasitism of the first generation has been slightly greater than that of the second. A few individuals of the tachinid *Exorista nigripalpis* Towns. have been reared from *P. nubilalis* larvae collected in New

York State, but less than 1 per cent of the hosts collected were parasitized by this species, and no other parasites have been recorded in this area to date. Table 45 summarizes the results of the collections of *P. nubilalis* larvae and pupae in New England to determine parasitism during the period from 1919 to 1921, inclusive.

TABLE 45.—*Parasitism of Pyrausta nubilalsis larvae and pupae by various Diptera and Hymenoptera in New England*

LARVAL COLLECTIONS

Year	First generation			Second generation		
	Number collected	Number parasitized	Per cent of parasitism	Number collected	Number parasitized	Per cent of parasitism
1919	5,525	80	1.45	6,231	2	0.03
1920	4,741	68	1.43	17,951	49	.27
1921	7,577	133	1.75	4,241	22	.52
Total	17,843	281		28,423	73	
Average			1.57			.26

PUPAL COLLECTIONS

Year	First generation			Second generation		
	Number collected	Number parasitized	Per cent of parasitism	Number collected	Number parasitized	Per cent of parasitism
1920	536	27	5.04	4,497	6	0.13
1921	2,905	65	2.24	2,801	4	.14
Total	3,441	92		7,298	10	
Average			2.67			.137

These figures on parasite rearings do not, of course, show the actual percentages of the host killed under field conditions by the action of parasite adults and from which no parasites are reared, but it is evident from the data in Table 45 that but little help can be expected of the native parasites of the larva and pupa in suppressing *P. nubilalis.*

FOREIGN PARASITES

Foreign literature contains very few records of parasites bred from *P. nubilalis* in any of its stages, and most of the literature dealing with the species emphasizes the absence of any parasites. Schmidt (*54*) in Austria, and Köllar (*34, p. 108*) in Germany, reared hymenopterous parasites from *P. nubilalis* larvae, but the species concerned and their status were not mentioned. Jablonowski (*29*) in Hungary reared a single individual of *Masicera senilis* Rond. from the larva, and two or three individuals of undetermined parasitic wasps from larvae and pupae. The same author found *P. nubilalis* eggs parasitized by a very small unknown hymenopteron, but it was not possible to estimate the economic importance of this parasite. The author also mentions in this connection that *Oophthora semblidis* Aur. is known as an egg parasite of many insects in Europe, and intimates that this may be the species concerned. Kostinsky recorded the rearing of parasites from *P. nubilalis* in Russia (Kiev) and Dobrodeiv (*14*) in the Don Province of Russia, but their names or their importance are not mentioned.

During 1919 the Bureau of Entomology established a laboratory in southern France for the purpose of investigating the parasitic enemies of *Pyrausta nubilalis* in Europe, with a view of introducing the most promising species into this country. W. R. Thompson, in charge of this work, is now engaged with two assistants in conducting a study of the biology and economic importance of several species of parasites which he has found attacking *P. nubilalis* in France, Italy, and Belgium. Eight species of the more promising parasites of the corn-borer larva and pupa have already been sent to this country by Doctor Thompson and liberated in the severely infested portion of the New England area. These consisted of the hymenopterons *Habrobracon brevicornis* Wesm., *Eulimneria crassifemur* Thom., *Exeristes roborator* Fabr., *Angitia* (*Dioctes*) *punctoria* Roman, *Microgaster tibialis* Nees, *Phaeogenes planifrons* Wesm., and two tachinids, *Masicera senilis* Rond and *Zenillia roseanae* B. B. Prior to the introduction of these species Doctor Thompson conducted a thorough study of their habits, with special reference to the possibility of detrimental conflict between them.

In addition to the foregoing, Doctor Thompson reports that he has reared from *P. nubilalis* larvae the tachinid *Nemorilla maculosa* Meig. *Trichogramma* sp., probably closely allied to the American species, was also found as an egg parasite, but not very abundant. According to Doctor Thompson a few specimens of the tachinid *Dexodes nigripes* Fall. and of the hymenopteron *Eulophus* sp. have been reared from *P. nubilalis* larvae by Professor Silvestri at Naples, Italy.

The history, habits, and present status of the imported species of parasites have been reported (*31*) by D. W. Jones, of the Arlington, Mass., corn-borer laboratory, substantially as follows:

Zenillia roseanae B. B. is a tachinid of much promise which parasitizes small host larvae and emerges just before the pupation of the host. The two generations of this parasite synchronize perfectly with the seasonal history of its host in southern France. Hibernation occurs as a second-instar larva within the host. Ninety adults were liberated during 1920 and 784 adults were liberated in 1921. It is planned eventually to carry on an extensive rearing project with this species to furnish a large number for liberation.

Masicera senilis Rond. is a tachinid which is believed to be very closely related to the native species *M. myoidea* Desv. A total of 70 adults of this species were liberated in 1920 and 300 adults were liberated in 1921.

Eulimneria crassifemur Thom. is a large hymenopterous parasite having two generations a year in southern France. This species usually parasitizes small host larvae while they are in their feeding webs, and hibernates as a full-fed larva within a very compact cocoon. Thirty-one adults were liberated in 1920, 4,968 adults in 1921, 733 adults in 1923, and 128 adults in 1924.

Angitia (*Dioctes*) *punctoria* Roman is a very effective summer parasite in Italy. This species is very similar to *E. crassifemur* in appearance and habits, except that it parasitizes free-crawling larvae as well as those in feeding webs. Only 10 adults were liberated in 1921, 168 adults in 1922, and 555 adults in 1924.

Exeristes roborator Fabr., one of the old Pimpla group, is a large hymenopteron equipped with a long, powerful ovipositor. This species is able to locate and parasitize full-grown larvae through cornstalks and other large woody stalks in which host larvae may be present. It has several generations each year, and hibernates as a full-fed larva in a very thin, tough cocoon. In October, 1922, a total of 1,061 cocoons were received from France. This shipment produced 500 adults, of which 56 were liberated in the field during 1921 and the remainder were used in breeding experiments. With this breeding stock as a basis, a total of 28,935 adults were bred and liberated during 1923. In 1924, 11,341 were liberated in New England, 7,920 sent to Sandusky, Ohio, and 2,880 to Silver Creek, N. Y., for liberation. Females predominated, and through the use of a special emergence cage they were well mated before liberation.

Habrobracon brevicornis Wesm. is a small hymenopteron which paralyzes full-grown host larvae and deposits external eggs. The resulting larvae feed externally and produce an average of 18 cocoons per host. From 8 to 10 generations per year would be possible with this parasite, as the life cycle is very short, varying greatly with the temperature. Hibernation occurs in the adult stage. In September, 1921, a total of 1,210 cocoons were received from France. This shipment produced 715 males and 213 females. With this breeding stock as a basis, 400 adults were bred and liberated in 1921 and 1,054,000 in 1922. Late in 1924 approximately 25,000 were liberated in Sandusky, Ohio, and in Silver Creek, N. Y. In the 1921 liberations the females averaged only 14 per cent of the total whereas improved breeding methods during 1922 increased the proportion of females to 40 and later to 60 per cent.

Microgaster tibialis Nees is a small hymenopteron which has been particularly effective as a parasite of *P. nubilalis* larvae inhabiting weeds in northern France and Belgium, and is also found in corn in Italy. This species parasitizes second-instar host larvae, feeding internally and emerging from the host in the late fourth or early fifth instar. Hibernation occurs as a full-fed larva within a very tough white cocoon. A total of 100 cocoons were received from France in 1923, and although no liberations were made during 1923 an attempt was made to develop a satisfactory technic for rearing the species. There were 449 adults and 2,815 parasitized larvae liberated in 1924 in the Massachusetts area.

Phaeogenes planifrons Wesm. is a large hymenopterous parasite which emerges from the pupa. It is particularly valuable as a summer-generation parasite in Italy, according to Doctor Thompson's records. There were 1,460 adults liberated in New England in 1924.

RECOVERIES OF FOREIGN PARASITES

With the exception of *Habrobracon brevicornis*, no systematic collections for the recovery of liberated parasites have been attempted. The results in attempting to recover *H. brevicornis* were negative to January 1, 1925. Encouraging results, however, were secured with *Exeristes roborator* and *Microgaster tibialis.* Incidental collections during the summer of 1923 showed that a maximum of 8 per cent of the corn-borer larvae were parasitized by E. *roborator* in the vicinity of the colony sites in Massachusetts, and from 1 to 4 per cent of the larvae were parasitized in a cornfield 3 miles from one of the liberation points. One incidental recovery was made at a distance of 5 miles from the nearest point of liberation. Several recoveries were made of individuals of this species which had successfully passed the winter of 1923–24. A few cocoons of *M. tibialis* were also recovered during 1924 under circumstances which indicated that this species had passed at least one generation in the field since liberation in its new environment.

It is proposed to continue the large-scale rearing in the laboratory and liberation in the field with each of the parasitic species, for which a satisfactory rearing technic can be developed, supplemented by extensive collections abroad of the species which can not be successfully or economically reared in the laboratory. It is problematical, of course, whether any of these species will become permanently established in this country, and several years may elapse before the results will be definitely known.

PREDATORS

BIRDS

In the late winter and spring of 1922 as high as 95 per cent of the larvae were removed from standing cornstalks in some of the small home gardens in the environs of Boston, presumably by woodpeckers. Their beneficial activities were also noted in many widely separated localities in the New England area, and to a lesser extent in New York State. From 10 cornstalks used in one particular hibernation experiment at Arlington, Mass., 160 larvae out of a total of 200 (80 per cent) were removed from their burrows by birds during this period. A downy woodpecker (*Dryobates pubescens* Linn.) was observed drilling into these cornstalks and removing the larvae. Judging from the character of the holes made in the cornstalks by this individual in its search for the larvae (fig. 52), it seems probable that this and allied species may be credited with much of the work mentioned previously. Prior to 1922 only occasional instances of similar work in infested cornstalks had been observed. According to Barber (*6*), from a series of 20 special observation stations which were maintained at widely distributed points in New England during the winter of 1922–23, birds were found to have taken 61 per cent of the larvae in five of these stations, and the remaining 13 stations which were recovered in good condition exhibited little or no feeding by birds.

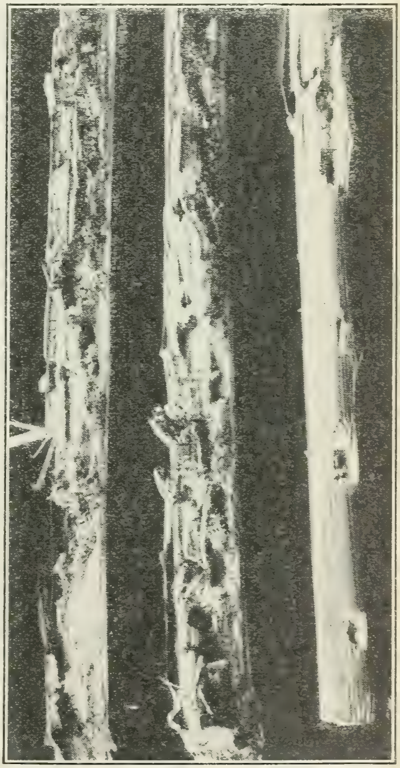

FIG. 52.—Cornstalks from which European corn borer larvae have been removed by birds, probably the downy woodpecker. Medford, Mass., April 13, 1922

The number of larvae taken by birds in the 18 stations recovered was 17 per cent of the total larvae involved. Judging from direct observation and from the character of the work, it is believed that the downy woodpecker was responsible for most of this beneficial activity. Each of the stations mentioned above consisted of 60 cornstalks tied to wooden stakes, simulating natural conditions, and containing an average of 27.5 larvae per stalk. In a similar experiment during the winter of 1923–24 an average of 19 per cent of the larvae involved were taken by birds. This series was conducted in 47 widely separated localities in the New England area.

With the exception of the somewhat local activity by woodpeckers, birds are not known to have exerted an important influence in reducing the numbers of the corn borer throughout the infested areas as a whole, although the comparative ease with which insectivorous birds may secure larvae from collapsed and broken-over cornstalks and other plant material, especially during the late fall and spring, would appear to render this source of food supply very attractive to them.

In one instance a robin (*Planesticus migratorius* Linn.) was observed, late in the spring, removing and devouring loose larvae from a heap of cornstalks. Robins, grackles, blackbirds, and starlings commonly frequent the vicinity of infested cornstalks and other plant material during the spring and have been observed feeding upon the larvae contained therein. Late in the spring many of the overwintering larvae are migrating in search of suitable quarters for pupation, and some of them are easily accessible to insectivorous birds. In several instances where infested ears of corn in the field were fed upon by crows, blackbirds, and pheasants, many of the *P. nubilalis* larvae known to have been feeding on the grain disappeared along with the corn, but no direct evidence of ingestion by birds could be obtained. Most of this type of bird activity was observed in sweet corn during the marketing season and in field corn before the grain had begun to harden. During the spring and fall of 1920 C. C. Sperry, of the Bureau of Biological Survey, investigated the relation of birds to the European corn borer in New England and found the remains of one larva in the stomach of a pheasant (*Phasianus torquatus* Gmelin) and the remains of six larvae in the stomach of a single starling (*Sturnus vulgaris* Linn.). No other species of birds were found feeding on the insect at this time.

OTHER PREDATORS

Larvae of the coccinellid *Megilla maculata* De G. have been frequently found devouring *P. nubilalis* eggs and larvae, and nymphs of the pentatomid *Podisus placidus* Uhl. and the reduviid *Sinea diadema* Fab. have been occasionally observed attacking the larvae. Many of the dead larvae found in partly or wholly decayed heaps of cornstalks in the spring, and in cornstalks or other plant material which has been buried in the soil, are frequented by mites, but it has not been determined whether these mites were the primary cause of death. Centipedes and the larvae or adults of several of the predacious beetles have also been found frequently in the decayed remains of such material. Whether any of these agencies were directly responsible for the death of the larvae is not known. In breeding cages several species of spiders have interfered with the experiments by attacking and killing migrating larvae, and occasional occurrences of a similar nature have been recorded in the field.

DISEASE

Occasionally, both in the field and in confinement, nearly full-grown larvae have been found during the summer and fall which apparently had succumbed to a disease resembling bacterial wilt. In the breeding cages at Silver Creek, N. Y., the rearing work was seriously hampered because of the mortality due to this disease. Specimens of larvae which had died, apparently from this disease, were submitted to G. F. White and A. T. Speare of the Bureau of Entomology, who reported that they were unable to find any protozoa, fungi, or polyhedral bodies in the samples submitted, but that an undetermined bacterium was present in great numbers. Later an attempt to isolate the causative organism was made by H. W. Allen of the Arlington, Mass., laboratory, in cooperation with R. W. Glaser of Bussey Institution, but the results were negative. Since only a comparatively small number of larvae have been killed by it in the field, this disease is evidently not important enough to be of material benefit.

CONTROL AND QUARANTINE

CONTROL

The details relating to the control, quarantine, and scouting phases of the European corn-borer activities will be given in a separate publication and may be summarized briefly as follows:

From the fact that the insect passes the greater part of its larval stage and its entire pupal stage within the host plant, thus affording but little chance for insecticidal or other remedial measures under large-scale field conditions, it is evident that the major control efforts should be directed toward cultural practices leading to the utilization or the destruction of infested plants, particularly by feeding to livestock, burning, or plowing under; supplemented by preventive agronomic adaptations in the culture of corn, particularly the selection of varieties least susceptible to severe injury, combined with the regulation of the time of planting these varieties to escape serious infestation and yet produce satisfactory yields. None of the insecticides tested can be recommended for general use, although nicotine dusts containing 2 or more per cent of free nicotine directed against the newly hatched larvae have given encouraging results in limiting injury to valuable crops of corn. The possibility of developing more effective treatments is still under investigation.

When considering general control measures for the corn borer it is necessary to make proper allowance for the fact that two generations occur annually in the New England area and that in this area the insect infests commonly a great variety of plants, including corn, vegetables, flowers, field crops, and large-stemmed grasses and weeds; whereas in the western areas, including New York, Pennsylvania, Ohio, and Michigan, the corn borer is single brooded and is confined principally to corn. In New England, therefore, it is necessary to utilize or destroy all plants or crop residues which are listed as hosts of the corn borer, and in the middle western area the control efforts are directed principally against the corn plant and its residues, under present conditions.

The value of corn and other plants for fodder is not materially lessened when infested by the corn borer, except under conditions of extreme infestation. The proper ensiling or shredding of such infested plants leads to the destruction of the borers contained therein. Feeding infested fodder direct to livestock is an effective method, providing all uneaten portions are collected and destroyed. The burning of infested material is, of course, a method of wide application, and although not a desirable agronomic practice in many respects, it is very effective when conducted in a thorough manner. In all methods of cutting cornstalks preparatory to their utilization or destruction, the stalks should be cut at or near the surface of the soil and as early in the season as possible, since there is a decided movement of the borers to the lower part of the stalk during the later part of the season. Based upon the results of plowing experiments to date, it appears that clean plowing is to be recommended for the destruction of cornstalks, corn stubble, and other infested material remaining in the field, which it is impracticable to eliminate by burning or feeding. Late fall plowing in the two-generation area of New England has proved more effective than spring plowing, but in the middle West it appears from results of experiments to date that *clean* plowing at any season is effective.

Relative to the selection of varieties as a cultural practice, none tested have shown any indication of possessing practical immunity to attack, but those varieties characterized by large stalks and ears have shown a greater resistance to severe injury by the corn borer than the varieties which have smaller stalks and ears.

Experimental data and field observations have shown in general that in the single-generation areas field and sweet corn planted during April or early May have sustained the maximum infestation and plantings made before the last week in May sustained greater injury than fields planted later, whereas plantings made after the first week of June suffered little or no injury. In the two-generation area of New England the early and the late plantings sustained the heaviest infestations, irrespective of type or variety, whereas plantings made during the period from approximately May 20 to May 30 have, in general, escaped serious injury. Phenological observations are now in progress having for their object the application of plant-development phenomena as an indication of the most favorable planting period, irrespective of calendar dates, in order that the vagaries of the seasons may be discounted.

Although the earliest planted fields of sweet corn have almost invariably sustained the maximum infestations in both the one and the two generation areas, thus indicating the possibility of using early planted sweet corn as a trap crop, actual attempts to apply this method of field control have thus far failed to show appreciable benefits, except under restricted conditions.

QUARANTINE

Quarantines have been established by the Federal authorities and by the various States concerned, which prohibit the movement out of infested areas of all plants and plant products which are likely to harbor the European corn borer. In the two-generation area this quarantine applies to corn and broomcorn, including all parts of the stalk, all sorghum, Sudan grass, celery, green beans in the pod, beets with top, rhubarb, chrysanthemum, aster, cosmos, zinnia, hollyhock, gladiolus, dahlia, and oat and rye straw as such or when used as packing material. In the single-generation areas the quarantine applies to corn, broomcorn, and all sorghum and Sudan grass, except the grain or seeds thereof when properly cleaned.

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SUPPLEMENT

In addition to the material presented in this bulletin, it seems desirable to summarize a few of the more important recent developments which have occurred since the manuscript was prepared. The following matter therefore has been included as a supplement.

DISTRIBUTION

At the close of 1926 the European corn borer had extended its range in the middle western portion of the United States to include the area shown on the accompanying map (fig. A). The entrance of the insect into the extensive corn-producing regions of Michigan, Ohio, and Indiana is fraught with possibilities of great economic losses. Dispersion of the corn borer in New England recently has been very limited and the area now infested is practically the same as indicated in the map included in the body of this bulletin. Slight extensions have occurred along the Connecticut shore line, on Long Island, and on Staten Island. Two small, independent infestations have been found in the Bayonne and Jersey City sections of New Jersey. Since the summer of 1923 the corn-borer situation in southern Ontario, Canada, has rapidly grown worse. At the close of 1924 the Dominion entomologists reported that commercial losses occurred in 21 townships located in Oxford, Elgin, Middlesex, Kent, and Essex Counties, where the stalk infestation varied from 50 to 100 per cent. "In one canning district 25 per cent of the contracted acreage was refused at the factory on account of

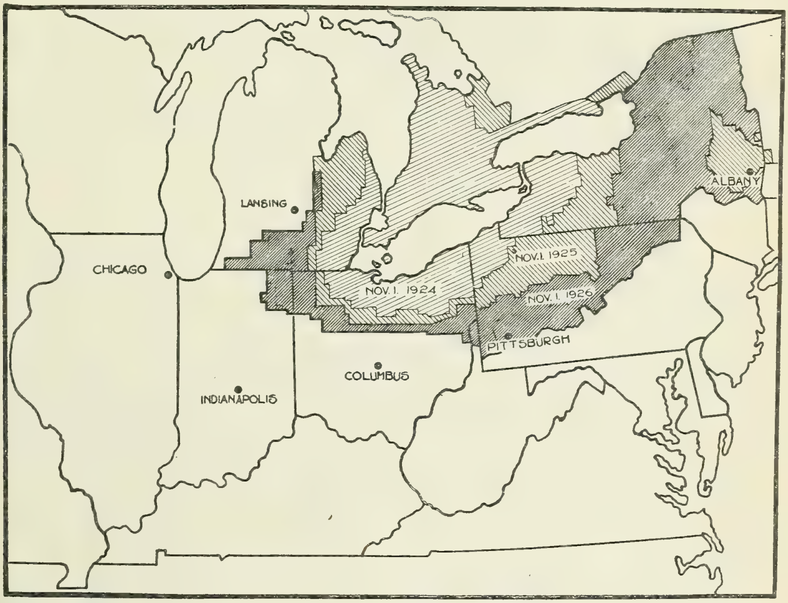

FIG. A.—Map showing the distribution of the European corn borer as known November 1, 1926. The outside (darkly shaded area) indicates the spread of the pest which is believed to have occurred during the summer of 1926. (Infested area in New England not shown.)

the severe corn-borer infestation." By the close of 1925 the course of the infestation had progressed so that in Kent and Essex Counties the crop throughout at least 400 square miles was completely ruined. Control measures were adopted very slowly by growers, as there existed no legislation requiring their adoption. This situation culminated during 1926, when it was found that throughout an area of 1,200 square miles the corn acreage had been reduced to 10 per cent of the land devoted to that purpose in 1922. In this area of intense infestation many fields showed a loss of the entire crop and losses of 75 per cent were common. Legislation requiring corn growers to clean up their fields became effective October 1 of that year. In the meantime the infestation in Canada had progressed eastwardly, completely surrounding Lake Ontario and joining with the infested area in New York, which had made progress along the southern shore of the lake. Distribution surveys in southern and central Europe have demonstrated the presence of the borer in practically all areas where corn and other susceptible crops are grown.

HOST PLANTS

No change has occurred in the status of corn as the preferred host of the European corn borer in America, since in all areas it continues to be more generally infested and sustains more serious injury than any other plant attacked.

In the middle western areas a light infestation has developed in several of the more susceptible weeds and field crops when such plants were associated with badly infested corn. No severe economic injury, however, to crops other than corn has occurred in these areas to date. The corn borer has been found infesting a total of 46 species of plants (principally large succulent weeds) in western New York, 18 species in Ohio, and 8 species in Michigan. The plants of most of those species function primarily as shelter plants rather than as true food plants.

In New England a total of 224 species have been recorded as hosts of the corn borer. In those species are also included all of the western host species. Of the total number of species not more than 38 are known to constitute true food plants. The severity of the infestation in vegetables, field crops, flowers, and weeds has decreased in New England during 1925 and 1926 as a phase of the general reduction in the importance of the insect as a pest in that region.

EXTENT OF INJURY AND ECONOMIC LOSS

In Michigan, Indiana, Pennsylvania, and Ohio, with the exception of a few fields in northwestern Ohio, there has been very little economic loss caused by the corn borer to the close of 1926. In western New York, however, the estimated commercial loss exceeded 25 per cent in certain dent cornfields grown for grain in the older portion of the infested area, while the loss in sweet corn ears for canning in 1926 reached approximately the same figure (24.8 per cent).

The widespread dispersal of the pest in this entire Lake Erie-Lake Ontario region during 1925 and 1926 was accompanied by an increase in intensity of infestation which amounted in 1926 to approximately

500 per cent for the area, when compared with conditions existing in 1925 (based upon larval population). Should the rate of annual increase which prevailed during the years 1923 to 1926 be continued, it appears reasonable to expect that losses will become general throughout this area in the near future, unless recommended control practices are strictly and generally followed.

An analysis of the data from 46 townships in New England showed a decrease of 38 per cent in intensity of infestation for 1926 as compared with 1925 (based upon larval population). Great decreases were especially apparent in commercial sweet corn plantings where an average of 20 per cent ear infestation existing in 1922 had been reduced to approximately 5 per cent in 1925 and to slightly less than 5 per cent in 1926. Similar reductions of infestation and damage were observed in susceptible vegetables and flowers, particularly in beets, beans, celery, rhubarb, potatoes, gladioli, dahlias, asters, and greenhouse chrysanthemums.

Detailed studies pertaining to the effect of borer injury to the cornstalks on the number, weight, and quality of ears, and on the grain produced, have demonstrated that this indirect injury usually is far more important than the direct injury to the ears caused by the larvae feeding thereon.

A remarkable decrease has been observed in the larval populations in areas of weeds and large-stemmed grasses formerly existing in the New England area. This former source of infestation, from which large numbers of moths issued to deposit their eggs upon cultivated crops, has been removed as a result of the enforcement of the Massachusetts law requiring clean-up action, plus the experience of local vegetable growers who have learned the necessity of clean culture.

SEASONAL HISTORY

Only one generation annually of the corn borer has developed in New York (not including the New York Bay area), Pennsylvania, Ohio, Michigan, and Indiana, although occasional instances of summer pupation, denoting a two-generation tendency, have been observed each year.

Two generations have developed both in New England and in the scattered infestations in the New York Bay area each year, although the percentage of individuals developing a second generation has varied from 40 to 100 per cent in different years. No indication of a third generation was observed in 1925 or 1926.

An analysis of meteorological data for New England with reference to the generation cycle has shown that a preponderance of precipitation, coupled with normal temperatures in March, April, and May, and followed by a dry June, induced an early start of the corn borer in New England. Under these conditions a complete second generation has developed. On the other hand, a deficiency in precipitation during March, April, and May, followed by a rainy June, was unfavorable to the insect. Under such conditions there has been a diminution in the number of individuals developing a second generation, with a consequent reduction of injury caused by the insect.

Single-generation material transferred to a two-generation area in 1920 and reared continuously there in large field cages retained its single-generation seasonal cycle at the close of 1926. Two-generation material treated in a similar manner retained the seasonal cycle of its original habitat in the same series of experiments. Since these experiments were conducted in the United States, where the corn borer may not yet have become thoroughly adapted to its environment, the results thus far obtained must be accepted with caution. All experimental cross breeding of two-generation and one-generation individuals has resulted in the production of two-generation progeny.

It has been demonstrated that the seasonal history, and especially the number of generations annually, is greatly influenced by the seasonal distribution of temperature and precipitation.

LARVAL HABITS

Studies to determine the percentage of larval establishment on corn have shown that an average of from 10 to 15 per cent of all larvae emerging from the eggs succeed in establishing themselves in or on the plant and reach maturity. This percentage of larval establishment may vary greatly in individual instances according to climatic conditions, type, variety, and strain of corn, and the condition of the individual host plant.

Definite records were obtained, as a result of extensive studies, that less than 1 per cent of full-grown larvae were able to migrate for a distance of 30 feet. About 2 per cent of the borers involved migrated a distance of 25 feet. The typical farm fence row, or field border, provides an ideal shelter for larvae migrating from plowed fields or elsewhere, particularly when such refuges contain large growths of weeds.

The average winter mortality above ground remains at about 10 per cent, as previously reported, and there does not appear to be any climatic limitation to the distribution or multiplication of the borer which depends upon winter mortality. Moisture secured by contact immediately prior to pupation seems essential for overwintering larvae.

Although many of the larvae contained in cornstalks that were stored indoors died as a result of the deprivation of contact moisture (so essential for the completion of histolysis) and the subsequent development of the survivors was delayed, a very large percentage of such larvae completed their development under storage conditions similar to those found on the average farm. Moreover, adults emerging from such storage conditions late in the season deposited eggs which developed into mature larvae before the end of the season.

ADULT HABITS

Detailed biological studies have demonstrated that the fecundity of the moths is greatly influenced by the character of the weather which occurs during their period of oviposition. Warm nights with abundant moisture, and the absence of heavy dashing rains, are conducive to maximum oviposition.

A study of wind movement during the flight period of European corn borer adults, in the Lake Erie region, has indicated strongly that dispersion to neighboring States probably occurred from the severely infested areas of Ontario. This method of natural dispersion was especially important during 1926, when the nocturnal temperatures and the direction of the prevailing wind during critical periods were both very favorable for the flight of large numbers of the moths.

PARASITES

NATIVE

Native parasites have not exhibited any tendency to increase their effectiveness as natural enemies of the corn borer. The egg-parasite *Trichogramma minutum* Riley continues periodically to parasitize considerable numbers of the eggs, but its effectiveness is confined usually to the second-generation eggs in New England every second or third year. A few additional species parasitic on the larvae and pupae of the corn borer have been recorded, but their combined parasitism usually has affected less than 1 per cent of the total number of hosts collected or observed each year.

FOREIGN

Including the month of October, 1926, a total of about 225,000 foreign parasites have been liberated in nine different locations of the corn-borer infested areas of Michigan, Indiana, Ohio, Pennsylvania, and New York. Seven distinct species were involved in these liberations, viz: *Exeristes roborator* Fab., *Microgaster tibialis* Nees, *Habrobracon brevicornis* Wesm., *Eulimneria crassifemur* Thom., *Apanteles* sp., *Angitia punctoria* Roman, and *Phaeogenes planifrons* Wesm. Recoveries of *E. roborator* were made in New York during 1924, 1925, and 1926. This species was recovered in Ohio during 1925 and 1926. A very recent recovery of what may prove to be *M. tibialis* was made in Ohio. Special precautions, of course, were taken to prevent the escape of foreign hyperparasites.

Similar introduction work in New England has resulted in the liberation of about 1,187,000 foreign parasites in infested cornfields of that section. Ten different parasitic species were involved, consisting of the seven species listed in the preceding paragraph and in addition *Macrocentrus* sp., *Zenillia roseanae* B. B. and *Masicera senilis* Rond. Five species of these foreign parasites have been recovered in New England under circumstances indicating their permanent establishment, viz: *E. roborator*, *M. tibialis*, *E. crassifemur*, *A. punctoria*, and *P. planifrons.* In certain fields the collections have demonstrated that the prevailing total parasitism by the foreign species exceeds that of the native species. The rate of importation of foreign parasites from Europe has been increased and preliminary shipments have been received from India. It is expected that this work will be greatly stressed in the near future.

CONTROL

None of the types, varieties, or strains of corn thus far tested has shown any practical immunity to corn-borer attack except when involved with time of planting such varieties.

Those varieties of corn characterized by large stalks and ears have continued to exhibit a greater resistance to severe injury by the corn borer than the varieties which possess smaller stalks and ears.

PLOWING AS A MEANS OF CONTROL

Recent field experiments conducted by the bureau in the Lake Erie region have demonstrated the value and necessity of plowing under cornstalks and stubble as a means of corn-borer control. The effectiveness of plowing depends upon turning under the corn refuse and other plant débris so completely that none of it remains upon the soil surface. It requires also that the material shall not be dragged to the surface by later cultivation.

Clean plowing is the best practical method of control for application to fields containing high stubble or stalks in case it is impracticable to cut the stalks close to the ground and dispose of them by feeding or burning. Existing methods of cutting stalks or breaking them off at the soil surface, raking them into windrows, and burning them are less effective than clean plowing alone, except where such raking and burning are followed by plowing under the remaining débris.

In the Bono-Reno area of northwestern Ohio during May and June, 1926, the number of borers per acre remaining in cornfields which had been poled, raked, and burned, or disked for small grain, was nearly twice as great as the number remaining in fields where cornstalks or stubble had been plowed under.

In disked corn-stubble fields where small grains were seeded the previous fall or in the spring, 89 per cent of the original borers remained alive in the corn remnants and other plant débris on the soil surface.

Studies made in five plowed fields of Lucas County, Ohio, revealed that on an average 75 per cent of the borers were killed by the operation, although no special effort was made to plow under cleanly. Two of these fields contained standing stalks and three were in high stubble.

Similar field work at Silver Creek, N. Y., showed an average of 97 per cent of the borers killed in three fields where standing stalks were poled down and then plowed under. In three fields where high stubble was plowed under, an average of 78 per cent of the borers were killed.

Less than 10 per cent on an average were killed by winter conditions, predators, parasites, and disease.

In the region previously mentioned an average of 59 per cent of the borers were killed by poling, raking, and burning the standing stalks in four fields. Many living borers were found in pieces of stalks not burned properly, as well as in stalks not broken off during the poling process, and in stalks missed by the rake. Fourteen per cent of the borer population were left in small pieces of corn husk, leaves, etc., which it was not possible to gather with the type of rake ordinarily used for such purposes.

DISKED CORNFIELDS SHOW VERY POOR RESULTS

In four fields of high stubble where oats were seeded after disking, without previous cultivation, only 11 per cent of the borers were killed. Therefore, the seeding of small grain on disked corn stubble or stalks is a dangerous practice under corn-borer conditions, since it leaves so many of the borers alive. The growing grain also provides shade and ideal protection from the wind for the borers left in such fields during the late spring.

Regardless of any necessary change in farm practice, the disking for small grain on infested corn lands will have to be discontinued if the corn borer is to be held in check. Where unavoidable, this practice should be limited to fields in which the operations of cutting or breaking off the stalks at the soil surface and completely disposing of them together with all trash, by burning or otherwise, have been carefully conducted.

In a field where standing stalks were poled down, raked in windrows, and burned, and the remaining débris plowed under, practically all of the borers were killed. Although there were about 5,100 borers per acre in the standing stalks before operations began, no living borers could be found in such small portions of trash as remained. This method, if widely adopted, would act as a very severe check on corn-borer infestation, and therefore it is strongly recommended.

Although the plowing under of infested cornstalks and corn stubble has given encouraging results where carried on in a careful manner it should be emphasized that careless plowing leaves many pieces of stalks, stubble, weeds, etc., upon the soil surface and is not effective. This débris shelters many borers which crawl to the surface after being plowed under. They bore into, or encase themselves, in such débris, and here many of them transform into moths. Where such shelter is lacking the vast majority of the borers finally perish, either being eaten by birds, beetles, or ants, or killed by various native parasites or by exposure to the weather. The use of plows with wide bottoms and a chain or wire to aid in burying all débris is an important help in doing a clean job.

The importance of clean plowing was strikingly shown by a series of experimental tests at Bono, Ohio.

Infested cornstalks were plowed under at intervals from late September to mid-December, 1925, and were surrounded by "recovery traps." At least 38 per cent of the borers in these plowed-under stalks crawled to the soil surface during the fall and the following spring. The remaining 62 per cent died in the soil or were destroyed by their natural enemies and weather conditions after reaching the surface.

In tests where the soil surface was practically free of all plant débris an average of only 2 per cent of the plowed-down borers were able to find adequate shelter. In similar tests where the quantity of stalks on the soil surface was the same as on average fields in the vicinity, 13 per cent of the total borers plowed down found adequate shelter in débris on the surface. In two other tests where "recovery traps," which provided shelter, were placed 25 feet distant from the plowed area, and stalks were left on the soil surface in average quantity, 22 per cent of the total number of plowed-under borers succeeded in entering the surface débris. An additional 5 per cent crawled at least 25 feet to the "recovery traps."

Thus it is shown that under circumstances closely imitating field conditions following clean plowing only 2 per cent of the borers escaped destruction. On the other hand, where average quantities of corn remnants were left on the soil surface, from 13 to 22 per cent of the borers survived.

In certain small tests where minute examination was possible, evidence was obtained that 28 per cent of the borers had died in the soil.

CORNSTALKS IN BARNYARD, FEED LOT, AND MANURE MUST BE DESTROYED

The warning should be repeated against throwing large quantities of cornstalks and other corn remnants into the manure unless buried deeply within it. It is also dangerous to permit large quantities of cornstalks to accumulate in barnyards and feed lots. An examination of the cornstalks in barnyards and on the surface of manure piles of five typical farms in Lucas County, Ohio, showed borers present in such cornstalks at the rate of 51 borers per 1,000 linear feet of stalks. No living borers were found in stalks buried deeply in the manure or in shredded corn plants which had been used for feed or bedding.

Judging from the history of the corn borer in Europe and in America, the pest may be expected to cause more damage in areas where the farming practices allow large quantities of stalks to remain undestroyed on farms than in areas where less corn is grown and stalks and other corn remnants are promptly consumed or destroyed.

HUSKERS AND SHREDDERS VERY EFFECTIVE IN KILLING BORERS

The existing types of husking machines equipped with shredder heads or cutter heads, or combination shredder and cutter heads, kill most of the borers in infested cornstalks. The efficiency of the machines is increased where special care is taken to apply sufficient pressure on the snapping rolls to produce a crushing effect. In six tests wherein cornstalks infested by the corn borer were run through six different types of husking machines an average of 98 per cent of the borers were killed by the machine. The greater part of the remaining 2 per cent undoubtedly perished during the process of storing the shredded material, feeding it to livestock, and using the residue as bedding, ultimately to be trampled into the manure, as results from the general practice.

This method of disposing of fodder is strongly recommended, and its use in corn-borer territory should be greatly extended.

The cutting box as ordinarily used has not proved effective in killing borers contained in cornstalks. If used at all, it should be adjusted so as to cut the stalks in pieces not to exceed one-half inch in length.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

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